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The Bendix Corporation
Eclipse-Pioneer Division
Teterboro, New Jersey

Final Report, Phase 1

STUDY PROGRAM FOR ALL-WEATHER INSTRUMENT LANDING SYSTEM.

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This report has been prepared by the Bendix Corporation for the Systems Research and Development Service, (formerly Aviation Research and Development Service), Federal Aviation Agency, under Contract Number ARDS-572. The contents of this report reflect the views of the contractor, who is responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policy of the FAA.

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M. Brown

ABSTRACT

The Bendix Corporation, Teterboro, New Jersey, STUDY PROGRAM FOR ALL-WEATHER INSTRUMENT LANDING SYSTEM, October 15, 1962, 88 pages, 15 illustrations, Final Report (Contract Number ARDS-572).

This report specifies recommended system concepts for integration of an Instrument Panel best suited for monitoring an Automatic All-Weather Landing or conducting a manual landing in low-visibility, low-ceiling conditions.

The instrument panel displays recommended fulfill the requirements of presenting all the presently available navigation and landing air parameters required for this program.

The detailed panel layouts, block diagrams depicting the system interconnections, price, delivery, and other pertinent information have ~~has~~ been included to aid in the choice of the most economical and technically feasible system.

Since more than one instrument panel will meet the requirements for the All-Weather Landing Program, six layouts are presented for review and approval of the Project Manager. The conclusions and recommendations pertinent to this study program are presented in Section 5.0.

A survey of heads-up displays presently available has been conducted and our conclusion and recommendations are presented in Section 7.0.

FOREWORD

This report was prepared by the Eclipse-Pioneer Division of The Bendix Corporation as required by the Federal Aviation Agency under Contract FAA/ARDS-572, Project No. 114-15.

The entire study was administered by the Electrical Instruments Laboratory with J. McInerney as Project Manager reporting directly to M. Brown, (Chief Engineer). Messrs: P. Catapano, R. Lickel, D. Cohen, G. Weber, F. Sano, and M. Putzer contributed to the material contained in this report.

The cognizant FAA Project Manager was Mr. R. Munnikhuysen who provided valuable guidance throughout the project.

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SUMMARY

Instrumentation - It is our opinion that it is not possible to specify one instrument panel as being the one and only cockpit display for an All-Weather Landing Program. It is for this reason that a number of panel layouts are included, all of which are well within the state of the art, and have the capability of supplying the necessary information for monitoring an automatic or conducting a manual, All-Weather Landing. The final decision as to which instrument panel will be ultimately decided upon will naturally be based on many considerations, including the economic and technical aspects.

It must be emphasized that six panel configurations were presented solely to identify the types of displays which could be available for implementation of this program. However, the conclusions contained in Section 5.0 reflect the recommendations arrived at as a result of all considerations contained in this report.

Basically, three types of panel layouts are included, with an option of replacing the round dial presentation of Airspeed and Angle of Attack with a Vertical Scale Presentation of same on each.

It should be noted that the additional sensors (black boxes) required for the All-Weather Instrumentation Program, essentially are not affected by the choice of the panel layout.

The instrument panel to be located in the passenger's cabin will contain the same displays as provided for the pilot, with the exception of a clock.

In addition to the pilot's panel layouts and the block diagram showing the interconnection between the sensors and instruments for the pilot's display, a cross-feed drawing is included which shows the proposed signal flow for the pilot's, co-pilot's, passenger cabin instruments and auto-pilot.

A description of each configuration is included, together with the table of contents for the particular panel layout. All additional components required for a particular configuration are denoted by an asterisk. Specifications for these items are included in this report or referenced to an existing Mil Spec or Vendor Part No. Price and delivery information, available at this time, is included in the table of contents.

It must also be stated that every effort was made to minimize the cost of updating existing sensors in the aircraft, unless absolutely necessary. It is for this reason that the existing Radio Receivers, Compass System, and Vertical Gyro equipments have been retained.

The choice of SCAT versus Specialties is based on the fact that the SCAT system "anticipates" speed changes before they actually register on the airspeed indicator. This is accomplished on the SCAT unit by use of a gyro stabilized pendulum which senses horizontal acceleration or deceleration. In addition to this "lead" information, which is certainly advantageous, especially in a "go-around" procedure, SCAT has been certified by the FAA for use on the Convair 880 and Boeing 707-131B aircraft, and at this date, appears to be the speed control system most promising for commercial jet aircraft. In addition, per telephone conversation with Mr. J. Muir, (Atlantic City) on October 2, 1962, it was stated that the Specialties System is not operating properly at this time.

1. INTRODUCTION

This is the final report proposing a system design for suitable flight and navigation instrumentation for monitoring an automatic landing or conducting a manual landing in low visibility, low ceiling conditions.

Every effort was made to retain, as far as possible, all existing sensors and navigational aids, unless a definite advantage warranted the up-dating or replacement of such. In addition, the selection of additional equipment (instruments and sensors) was based on proven techniques, where possible.

It was necessary to specify some items which required development. The specifications for these components are contained herein. It was not the intent to provide a detailed specification for these items until the Project Manager has authorized approval for the proposed items.

It must be stated that price, delivery and technical information requested from some of the vendors has not been received. Thus, the choice of vendors who have the capability of providing the subject item was based only on such vendors who acknowledged and replied specifically to the inquiries.

The format which will be used in this report is as follows:

Section 2. -

1. Define the particular panel layout for the pilot's installation with its associated drawing.
2. Define a single installation block diagram for the particular panel.
3. Include a brief description of the operation of the new instruments.
4. Table of contents for the components required for the installation, (price, delivery, size, power, etc.)
5. Conclusion and remarks for the particular panel described.

A total of six different panels will be included, herafter referred to as Configuration #1 thru #6.

Section 3. - A description of a typical cross feed of information, including a block diagram for one of the panels selected. The cross-feed philosophy will not change as a result of the panel selected.

Section 4. - Specifications for items not presently available.

Section 5. - Conclusions of the study program.

Section 6. - General remarks concerning the panel to be installed in the passenger's cabin.

Section 7. - Comments on heads-up display.

2. PILOT'S INSTRUMENT PANEL

Six possible panel configurations are presented for evaluation. It is felt that this provides a cross-section of the various types of displays best suited for the All-Weather Landing Program.

2.1 Configuration #1

1. This panel configuration is shown in Figure 1. The panel is similar to the presently installed instrumentation with the following exceptions:

a. - A Vertical Scale display of Distance to Touchdown has been added.

b. - A Vertical Scale-Vertical Speed, Altitude, Terrain Clearance has been added.

c. - A Flight Director Phase Indicator which depicts the automatically activated modes of the Flight Director in the final approach has been added.

d. - A Bank of Comparator and Monitoring lights which provide the pilot with a warning, should failures occur in his displays or discrepancies exist between the sensors supplying the pilot's independent instrument system and the remainder of the instrument displays and autopilot.

The single installation block diagram for the #1 configuration is shown in Figure 1A. Although the block diagram is not shown for the second set of instruments to be located in the passenger's cabin, it would be identical to Figure 1A with the exception that the other set of sensors (Vertical Gyro, Compass, Central Air Data, etc), will provide the necessary signals, in addition to supplying, when applicable, the present co-pilot's installation and autopilot. The one exception is that the STR-30B Radio Altimeter will provide the absolute altitude reference rather than the FAA sponsored Radio Altimeter which supplies the pilot's instruments.

2. Description of Figure 1A. (Single Installation Block Diagram) The following information is displayed on the referenced instruments:

a. -Airspeed on the Kollsman Airspeed Indicator

b. -Angle of Attack on the Specialties Angle of Attack Indicator.

c. -Rate of Turn on the Rate of Turn Indicator.

d. -HZ-4 Horizon Flight Director Indicator.

1) Pitch and Roll Attitude on the Sperry HZ-4 Horizon Flight Director Indicator is supplied from the Vertical Gyro.

2) Pitch and roll Command on the cross pointers on the Sperry HZ-4 Horizon Flight Director Indicator is supplied from the Sperry Z-5 Computer.

The Roll Command computation will be based on the presently available inputs to the Sperry Flight Director Computer.

The Pitch Command computation will be based on conventional inputs for en route navigation but in the final approach mode (Glide Slope), the computer will be supplied with (a) Conventional Glide Slope
(b) Augmented Glide Slope, based on Glide Slope as the long term reference and augmented altitude rate as the short term reference.
(c) Flight Path Error, computed from Radar Altitude and Augmented Radar Altitude Rate.

The above inputs will automatically be supplied to the Flight Director Computer from the IVV, Augmented Glide Slope and Flare Module.

The Glide Slope signal will be supplied from the initiation of Glide Slope Engage to approximately 800 feet of altitude. The Augmented Glide Slope signal will be supplied from 800 feet to approximately 50 feet, and the flight path error (deviation from the prescribed exponential altitude flare path) will be supplied from 50 feet to touchdown. The particular mode of operation will be indicated by the Flight Director Phase Indicator.

In addition to the following input modifications to the pitch channel of the computer, provisions are proposed for use of the SCAT sensor to provide optimum "go-around" information for display on the Pitch Command cross pointer on the HZ-4.

If the decision is made to go-around, means will be provided to automatically position the Flight Director Mode Selector Switch to the go-around position. When the switch is in this position, the SCAT sensor will supply command information to the pitch bar on the HZ-4, Horizon Director Indicator.

e. - M. H. R. (Master Heading Reference) - This instrument will display heading information from #1 Compass and also supply heading to the co-pilot's RMI and the RMI in the passenger's cabin. The glide slope needle will display glide slope, augmented glide slope and flight path error. This will provide a displacement cross check for the Pitch Command indication on the HZ-4. Consideration was given to provide only glide slope to this needle in order to provide additional redundancy for the pitch axis. However, the quality of the glide slope signal at altitudes below 200 feet and the limitations of using glide slope for guidance near touchdown is the reason for the proposed choice.

f. - RMI (EP 36135) - The heading card will display compass information derived from the co-pilot's MHR. This provides a heading cross check for the pilot's MHR Indicator. The new RMI was selected since it had the VOR-ADF switching incorporated in the instrument. This provided for additional space since the VOR-ADF switches could be removed.

g. - Vertical Scale Display of Distance to Touchdown - This display will be activated at Glide Slope Engage. It is proposed that the distance to touchdown tape be driven from the units synchro rather than the distance potentiometer, in the DME unit, for the purpose of providing better resolution and accuracy. Since the display will not be activated until Glide Slope Engage, when the distance readout will always be less than ten miles, the unit synchro will show the correct distance to touchdown. It is felt that this larger distance display is superior to the analog tape display provided for in the modified AQU-4/A HSI. This indicator contains an integral servo amplifier.

h. - Vertical Scale Display of Vertical Speed, Barometric Altitude and Terrain Clearance - The Vertical Speed moving pointer will always be supplied with augmented altitude rate based on the Central Air Data barometric signal as the long term reference and normal acceleration by the short term reference.

The Central Air Data coarse and fine (altitude) synchros provide the inputs for the altitude display.

The Radar Altimeter (FAA sponsored) supplies the input for the terrain clearance display.

During the flare portion of the flight profile, the vertical speed pointer and the terrain clearance pointer should be coincident, indicating an exponential flare out.

i. - Radio Altitude Indicator (S. T. C.) - The operation of the Radar Altimeter remains unchanged. The STR 30-B Radio Altimeter sensor supplies this instrument.

j. - BLEU-Auto-Land Phase Indicator - This displays the automatic pilot mode of operation.

k. - Flight Director Phase Indicator - This will consist of three lamps, which, when energized from the IVV, augmented Glide Slope and Flare Module, will indicate the longitudinal mode of operation displayed on the pitch command bar of the Horizon Director Indicator. It is also suggested to incorporate a push to test button which will test all the lamps. A crosscheck between the BLEU-Auto-Land and Flight Director Phase Indicators will provide the pilot a means of assessing his flight director instrument display.

l. - Flight Director Comparator Lamps - This bank of lamps will provide a crosscheck between the sensors supplying the pilot's instrument panel and the sensors feeding the remaining instruments and automatic system. A detailed description is included in the <u>Monitor Comparator Warning System.</u>

l. 1- Flight Director Monitor Lamps - One vertical column of lamps will monitor the operation of instruments on the pilot's panel and the second column of lamps monitors the instruments in the passenger's cabin. A detailed description is also included in the <u>Monitor Comparator Warning System.</u>

l. 2- Every effort was made to provide a realistic degree of monitoring and comparison. It is realized that malfunctions would exist which will not be indicated by the Warning System. However, the extent of monitoring and comparison must be weighed against the complexity of offering a more complete warning system.

m. - The following units, although not mounted directly on the panel, are considered part of the display.

1) Peripheral Command Indicator

2) "Fast-Slow" Indicator

3) Mode Selector Switch

m. 1 - Peripheral Command Indicator (Collins) - This indicator will repeat Roll and Pitch Commands. The Flight Director Computer outputs will be processed through a coupler to provide the proper inputs to the PCI. Details of the coupler are not available at this time since information as to the signals required for the PCI have not been supplied by Collins. Another request was made of Collins for this information.

m. 2 - "Fast-Slow" Indicator - This indicator is a Safe-Flite product and will be driven from the SCAT Speed Command System.

m. 3 - Mode Selector Switch - It is proposed that this switch be a solenoid held type switch which is mechanically spring loaded to the "go-around" position.

In this way, when the Flight Director Disengage button is pressed, removing power from the mode selector switch solenoid, the switch will automatically position to the "go-around" mode. The automatic selection of this mode will provide for display of zero Roll Command on the Horizon Flight Director Indicator and a pitch command based on information supplied by the SCAT speed control system. Proper interlocking of the SCAT inherent monitoring provisions must be included, so that, in the event of a SCAT failure, a means is provided to drive the pitch command bar out of view. A crosscheck of the fast-slow indicator would also show if SCAT is functioning properly. If a failure does occur in SCAT, a flag will show on the fast-slow indicator.

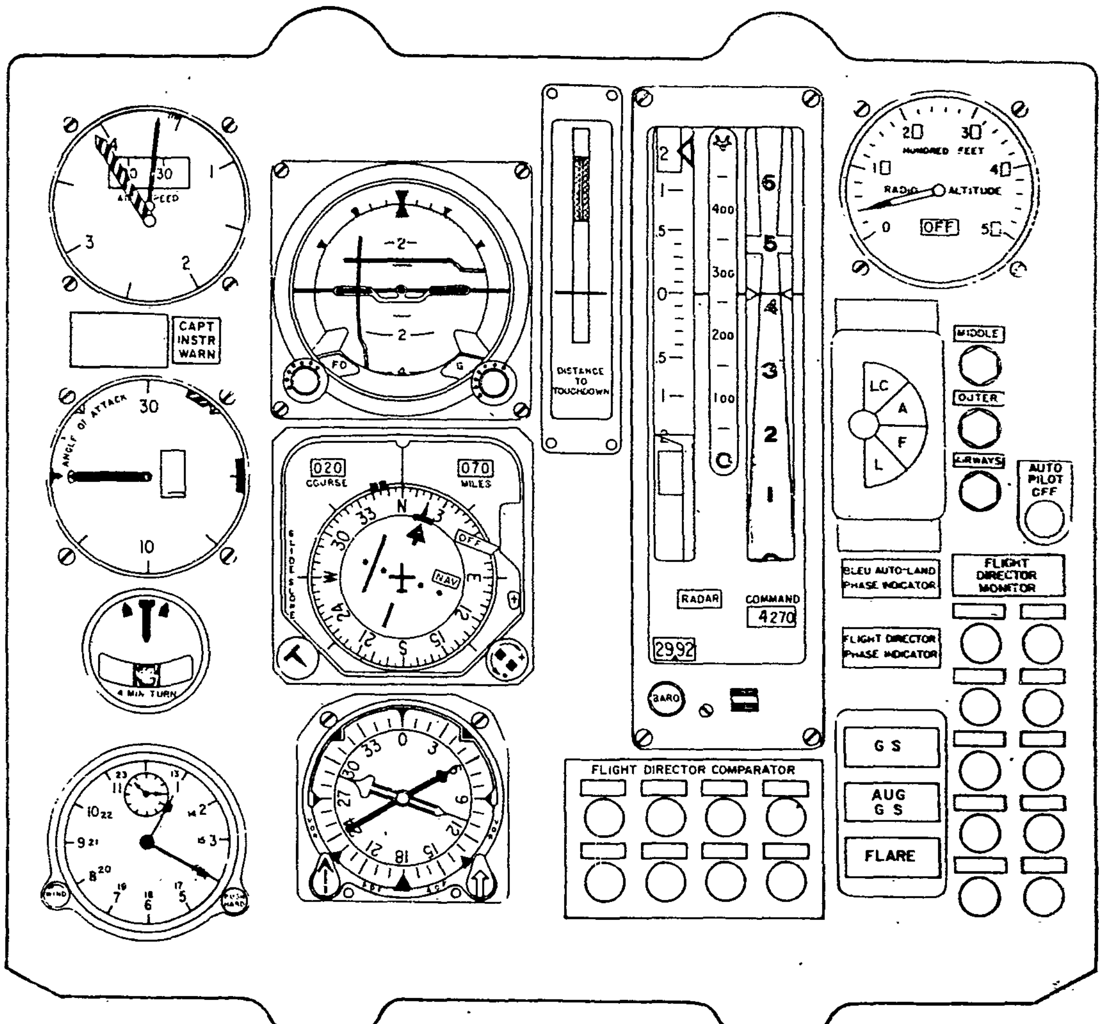

FIGURE-1

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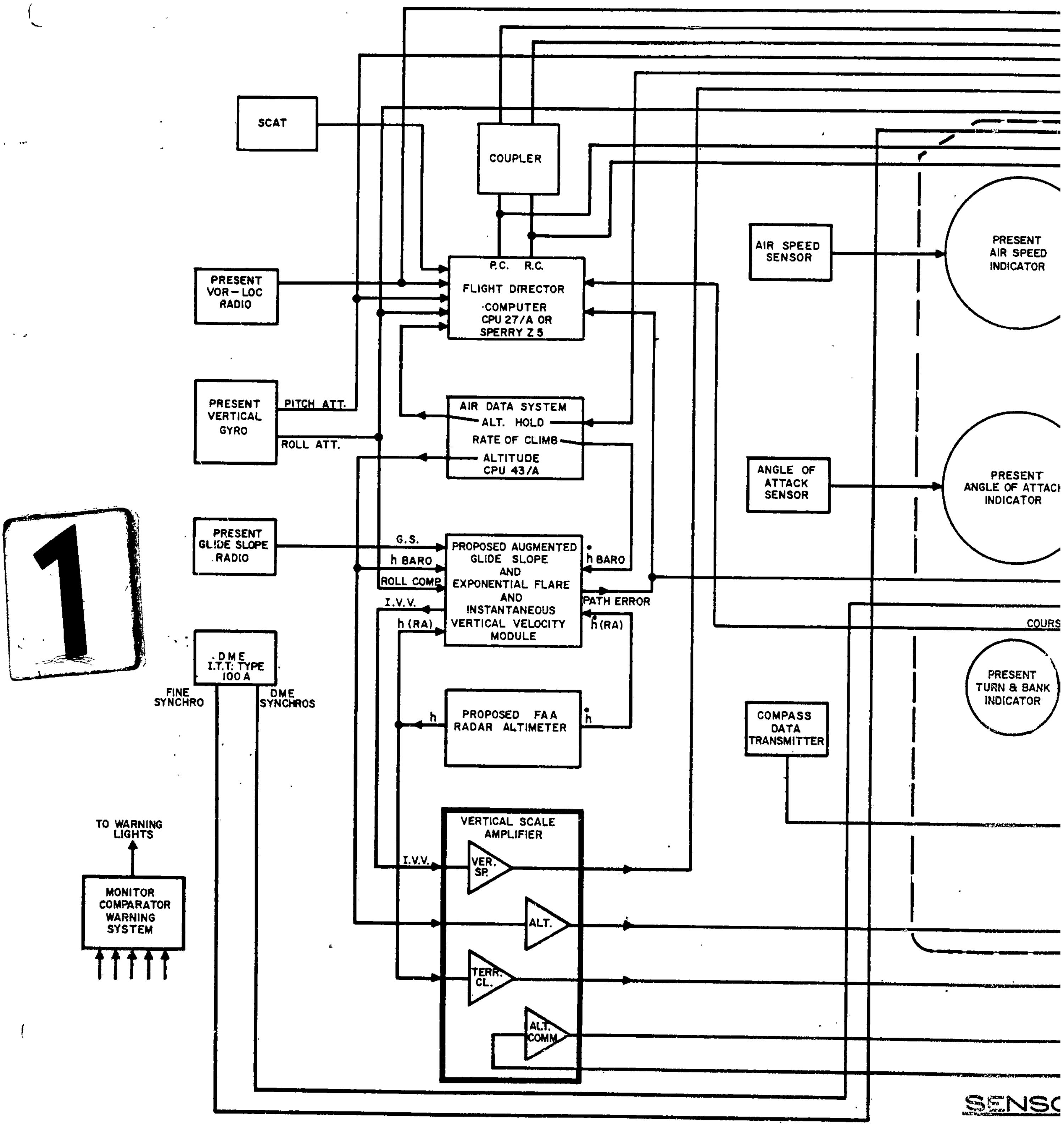
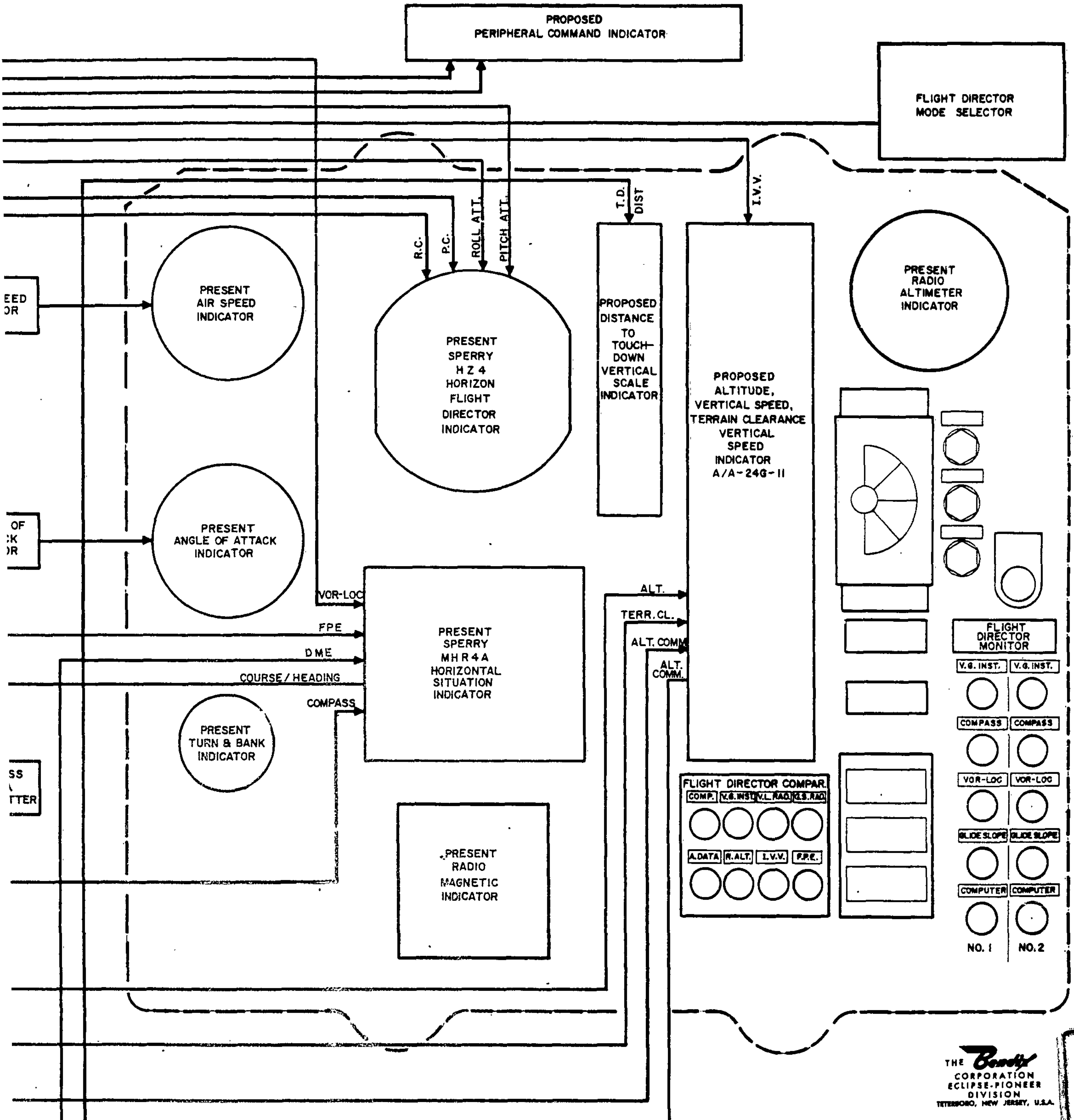


SCAT
COUPLER
P.C. R.C.
FLIGHT DIRECTOR COMPUTER CPU 27/A OR SPERRY Z 5
PRESENT VOR—LOC RADIO
PRESENT VERTICAL GYRO
PITCH ATT.
ROLL ATT.
AIR DATA SYSTEM
ALT. HOLD
RATE OF CLIMB
ALTITUDE CPU 43/A
PRESENT GLIDE SLOPE RADIO
G.S.
h BARO
ROLL COMP
I.V.V.
h (RA)
PROPOSED AUGMENTED GLIDE SLOPE AND EXPONENTIAL FLARE AND INSTANTANEOUS VERTICAL VELOCITY MODULE
ḣ BARO
PATH ERROR
ḣ (RA)
DME I.T.T. TYPE 100 A
FINE SYNCHRO
DME SYNCHROS
h
PROPOSED FAA RADAR ALTIMETER
ḣ
TO WARNING LIGHTS
MONITOR COMPARATOR WARNING SYSTEM
VERTICAL SCALE AMPLIFIER
I.V.V.
VER. SP.
ALT.
TERR. CL.
ALT. COMM.
AIR SPEED SENSOR
PRESENT AIR SPEED INDICATOR
ANGLE OF ATTACK SENSOR
PRESENT ANGLE OF ATTACK INDICATOR
COURS
PRESENT TURN & BANK INDICATOR
COMPASS DATA TRANSMITTER
SENSC



SENSOR INTERCONNECTION OF FIGURE 1 PANEL

FIGURE-1A

2

Remote Electronics

It can be seen in Figure 1A that the following additional black boxes are recommended for proper implementation of this system:

1. SCAT Speed Control System
2. Monitor Comparator Warning System
3. Central Air Data (CPU-43/A)
4. Augmented Glide Slope, Exponential Flare, Instantaneous Vertical Velocity Module
5. FAA sponsored Radar Altimeter
6. Vertical Scale Amplifier for use with Vertical Speed, Altitude and Terrain Clearance Vertical Scale Instrument
7. The coupler required to provide compatability between the flight director computer and the peripheral command indicator

It should be noted that each of the six configurations will require essentially the same sensors and couplers specified for Configuration #1.

Space is available for the physical location of the required additional remote equipment in the area directly across from the instrument Rack-1245-S 0846 (recorders).

A table of contents, Table I, is given below listing the components required for implementation of the proposed Configuration #1, Instrument Panel and Associated Sensors and Couplers. Items which are not presently installed are denoted by an asterisk and so far as possible, size, weight, etc., are reflected for such items.

Since the items not preceded by an asterisk are presently installed on the aircraft, details such as size, weight, etc., are not tabulated.

TABLE I (Configuration #1)

PANEL

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
1) Present Airspeed Indicator						
2) Present Angle of Attack Indicator						
3) Present Rate of Turn Indicator						
4) Present Clock						
5) Present Horizon Flight Director Indicator (HZ4)						
6) Present Horizontal Situation Indicator (MHR 4A)						
*7) Radio Magnetic Indicator 36135-C1	3.125 x 3.25 x 5 3/32	2.5 lb.	26V at 400 cycles 5 VA	$690.00	60-90 day (ARO)	
*8) Distance to Touch-down Ind. EP would propose	1.25 x 5.875 x 5.5	3.0 lb.	115V at 400 cycles 30 VA	$6000	5 month (estimate)	See Text
*9) Vert. Speed, Alt. Terrain Clear. Ind. (Vert Scale) EP would propose	3.0 x 10.5 x 8.5	10.5 lb.	Supplied by V/S Amp.	$32,618. includes Amps.	5 month (ARO)	mil-A-27671
10) Present Radio Altitude Ind.						

TABLE I (Configuration #1) (Cont'd)

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
11) Present Bleu Phase Ind.						
*12) Flight Dir. Phase Ind.	1.6875 x 3.5 x 2.0	.75 lb.	Supplied by IVV Aug GS and Flare Coupler	$100	1 Month (est)	See Text
*13) Flight Dir. Comparator Lamps	position as shown on panel layout		Supplied by Monitor-Comparator	$200	1 Month (est)	
*14) Flight Dir. Monitor Lamps	position as shown on panel layout		Supplied by Warning System	$200	1 Month (est)	
*15) Peripheral Command Ind. (above panel) (Collins)	8 1/4"x1 3/8" x3 1/2"	3 lbs	←—not available as of 12-12-62			→
*16) Mode Select Switch (above panel) (EP would propose)				$245	3 Months (estimated)	See Text
*17) Scat fast-slow Ind. (above panel) Safe-Flite	3.10x1.3x2.83	.4 lbs	5V/.3 Amps (lamps)	included with scat system price	90 day ARO	

TABLE 1

ASSOCIATED EQUIPMENT

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
*1) Scat System a) Lift Transducer 775 b) Flap Transmitter 925 c) Summing Unit 01AB03 (Safe Flite)	3 5/8 dia x4 15/16 2.06x2.7x 3.65 9 1/8x8x 12 3/4	1 lb 20 lb	115V-ac at 4 amp 28V-dc at 1 amp 26V-ac at 1 amp (System requirements)	$10,693.80/ System Price(includes indicator)	90 days ARO 120 day ARO 150 day ARO	
2) Present VOR-LOC Radio						
3) Present Glide Slope Radio						
4) Present Vert Gyro						
5) Present Distance Measuring Equipment						
*6) Monitor-Comp. Coupler(EP would propose)	3/4 ATR Short	12 lb	115V-ac at 400~ 70 VA 28V-dc 40 Watts	$23,000	6 month (estimate)	See Text
7) Present Flight Dir. Computer Z5						
*8) Central Air Data computer CPU/43A (EP would propose	1/2 ATR Long	24 lb	115V 400 cycle 47 VA	$17,000.0	7 month ARO	ARINC 545

TABLE 1

ASSOCIATED EQUIPMENT (Cont' d)

Component		Weight	Power	Unit Cost	Delivery	Spec
*9) IVV, Aug GS and Flare Module (EP would propose)	3/4 ATR Short	15 lb	115V 400~ 100VA 28V-dc 14 watts	$28, 000	6 Months (estimated)	See Text
*10) Radar Altimeter (FAA proposed)	729 cu. in (max)	15 lb	115V 400~ 28 V dc			FAA ltr #58
*11) Vertical Speed, Altitude and Terrain V/S amp EP would propose	4 7/16x 4 1/2x 10 29/32	8 lb	115V 400~ 63 VA	included with indicator		mil-A-27671
12) Present airspeed sensor						
13) Present angle of attack sensor						
14) Present rate of turn sensor						
15) Present C4-A Compass						
16) Present flight director amp.						
17) Present RMI amplifier						
*18) Peripheral command coupler EP would propose	←Information not available on requirements→ for coupler			$600	2 mo. (est) after technical information received from Collins	See Text

Electrical Load Analysis: - The following estimate is based on the single installation as shown in Figure 1A, and reflects only the additional power required for the proposed system.

115 V 400 Cycles	-	950 VA
26 V 400 Cycles	-	100 VA
28 V dc	-	45 VA

Conclusions With Regard to Configuration #1 - The instrumentation shown for Configuration #1 represents a system which requires the minimum amount of panel rework and yet affords a display which contains all the available information content and monitoring deemed necessary for an All-Weather Landing instrument system.

The longitudinal axis (pitch command) display of the flight director is now supplied with computed signals based on the unique flight path parameters required to perform an all weather landing. The addition of augmented glide slope and flare commands will provide for a more reliable display to the pilot as lower minimums are required.

The Vertical Scale Display of Distance to Touchdown will provide the pilot with not only distance information, but will indirectly provide an indication as to the rate at which he is approaching the end of the runway. It is felt that this rate indication is not as conveniently displayed on a counter type distance indicator. In addition, the resolution on the vertical scale display is much superior to that available on the counter type distance display.

The vertical scale display of vertical speed (augmented air data), terrain clearance and barometric altitude provides an integrated presentation to the pilot of his vertical situation. During the flare portion of the flight profile, the vertical speed pointer and terrain clearance symbol should be maintained in alignment (coincident), insuring an exponential flare path to touchdown.

The Monitor-Comparator Warning System provides a more thorough and eye-catching indication of failures which is certainly required for an all weather landing program.

The No. 2 column of lights shown under the Flight Director Monitor is associated with the instruments to be located in the passengers' cabin.

2.2 Configuration #2

The panel configuration is shown in Figure 2. The panel is similar to that presented in Figure 1 with the exception that the round dial angle of attack and air speed indicators are replaced with Vertical Scale Displays of same.

The Airspeed Indicator, will have monitoring and self test provisions.

Monitoring - The following malfunctions will be detectable by the integral monitor:

1. Open stator connections between the Central Air Data and instrument Follow-up Autosyn.
2. Loss of excitation in the CADC transmitter.
3. Open rotor in the CADC
4. Failure of the servo amplifier driving the follow-up autosyn in the indicator
5. Gear train hang-up in the indicator
6. Tape slippage in the indicator

It must be stated that this is not merely a "go-no go" type of monitor. The monitor is designed to detect airspeed errors to within ± 4 knots. Any failure in the airspeed chain from the CADC to the final display is immediately sensed. Should failure occur, a warning flag appears in the airspeed window.

Self Test (Air Speed Indicator) - Self test provisions are available, if desired. The checks can be performed during pre-flight check out or during flight. This gives assurance that the indicator is performing properly. Consideration has been given to checking the monitor section of the instrument during self test. Circuitry is provided in the self test sections to deliberately introduce a fault to determine that the monitor is operating properly.

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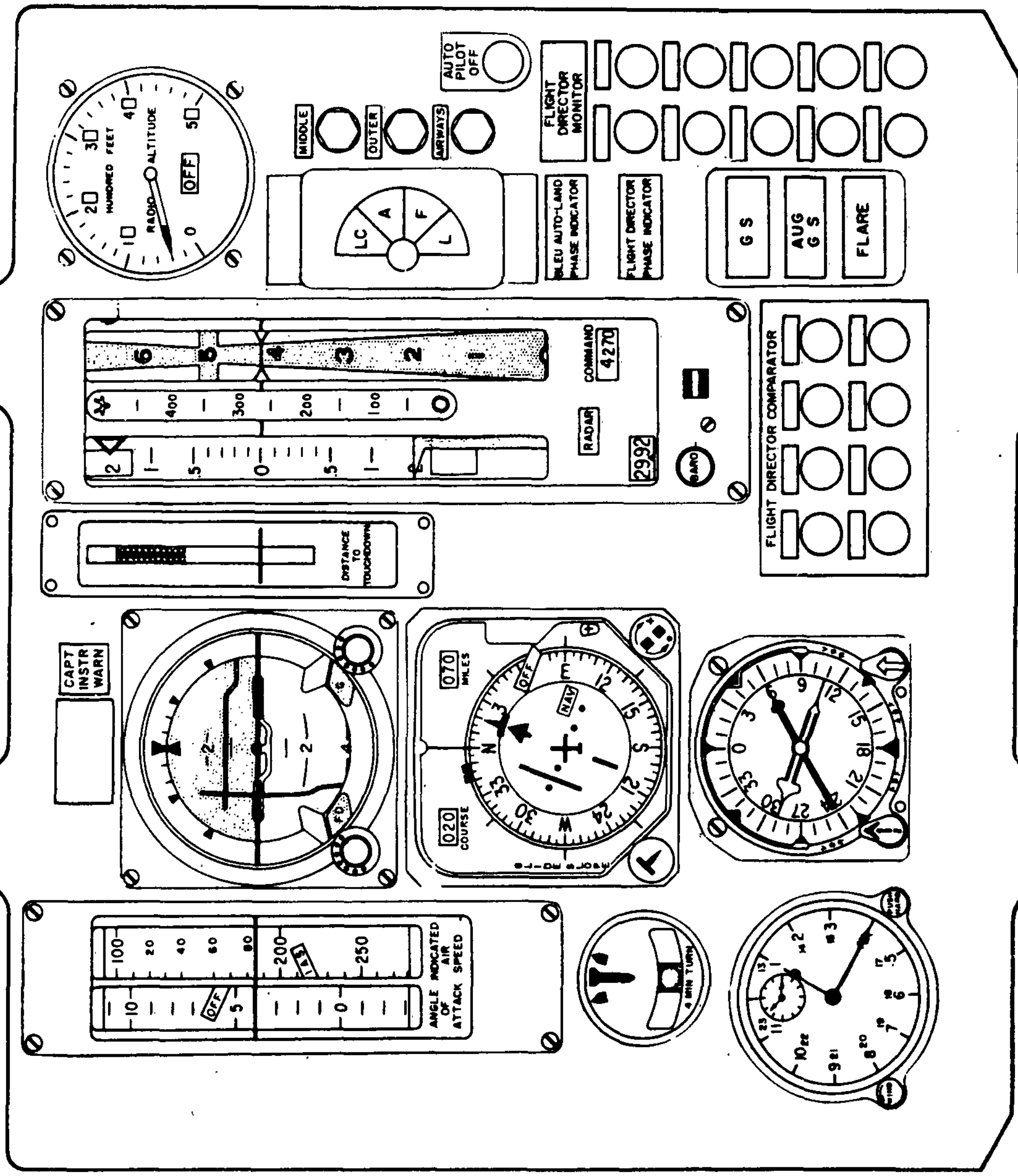
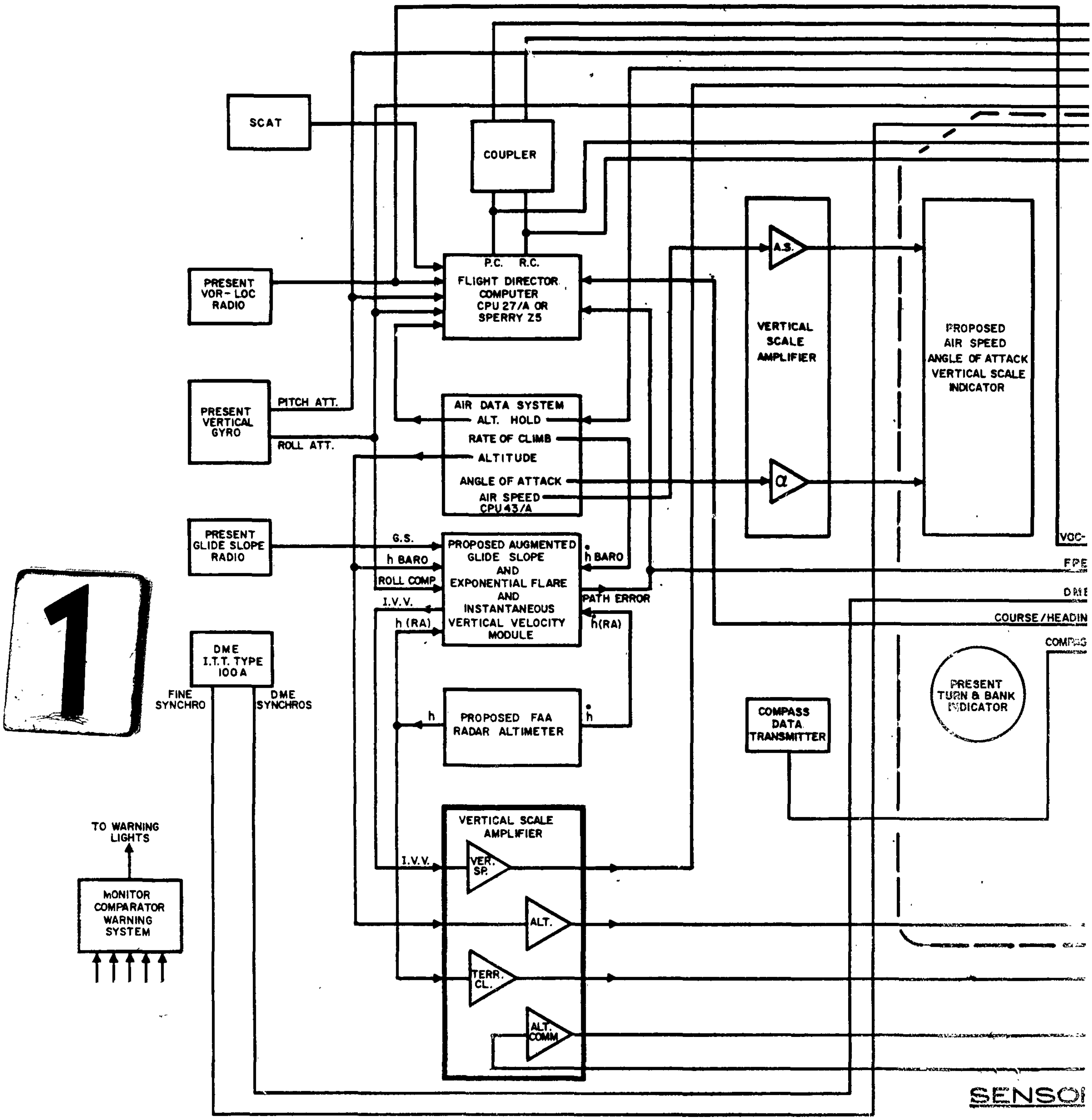


FIGURE- 2



SCAT
COUPLER
P.C.
R.C.
FLIGHT DIRECTOR COMPUTER CPU 27/A OR SPERRY Z5
PRESENT VOR-LOC RADIO
PRESENT VERTICAL GYRO
PITCH ATT.
ROLL ATT.
AIR DATA SYSTEM
ALT. HOLD
RATE OF CLIMB
ALTITUDE
ANGLE OF ATTACK
AIR SPEED
CPU 43/A
PRESENT GLIDE SLOPE RADIO
G.S.
h BARO
ROLL COMP.
I.V.V.
h (RA)
PROPOSED AUGMENTED GLIDE SLOPE AND EXPONENTIAL FLARE AND INSTANTANEOUS VERTICAL VELOCITY MODULE
ḣ BARO
PATH ERROR
ḣ(RA)
DME I.T.T. TYPE 100 A
FINE SYNCHRO
DME SYNCHROS
h
PROPOSED FAA RADAR ALTIMETER
ḣ
VERTICAL SCALE AMPLIFIER
A.S.
α
PROPOSED AIR SPEED ANGLE OF ATTACK VERTICAL SCALE INDICATOR
VOC-
FPE
DME
COURSE/HEADIN
COMPASS
PRESENT TURN & BANK INDICATOR
COMPASS DATA TRANSMITTER
TO WARNING LIGHTS
MONITOR COMPARATOR WARNING SYSTEM
VERTICAL SCALE AMPLIFIER
I.V.V.
VER. SP.
ALT.
TERR. CL.
ALT. COMM
SENSO
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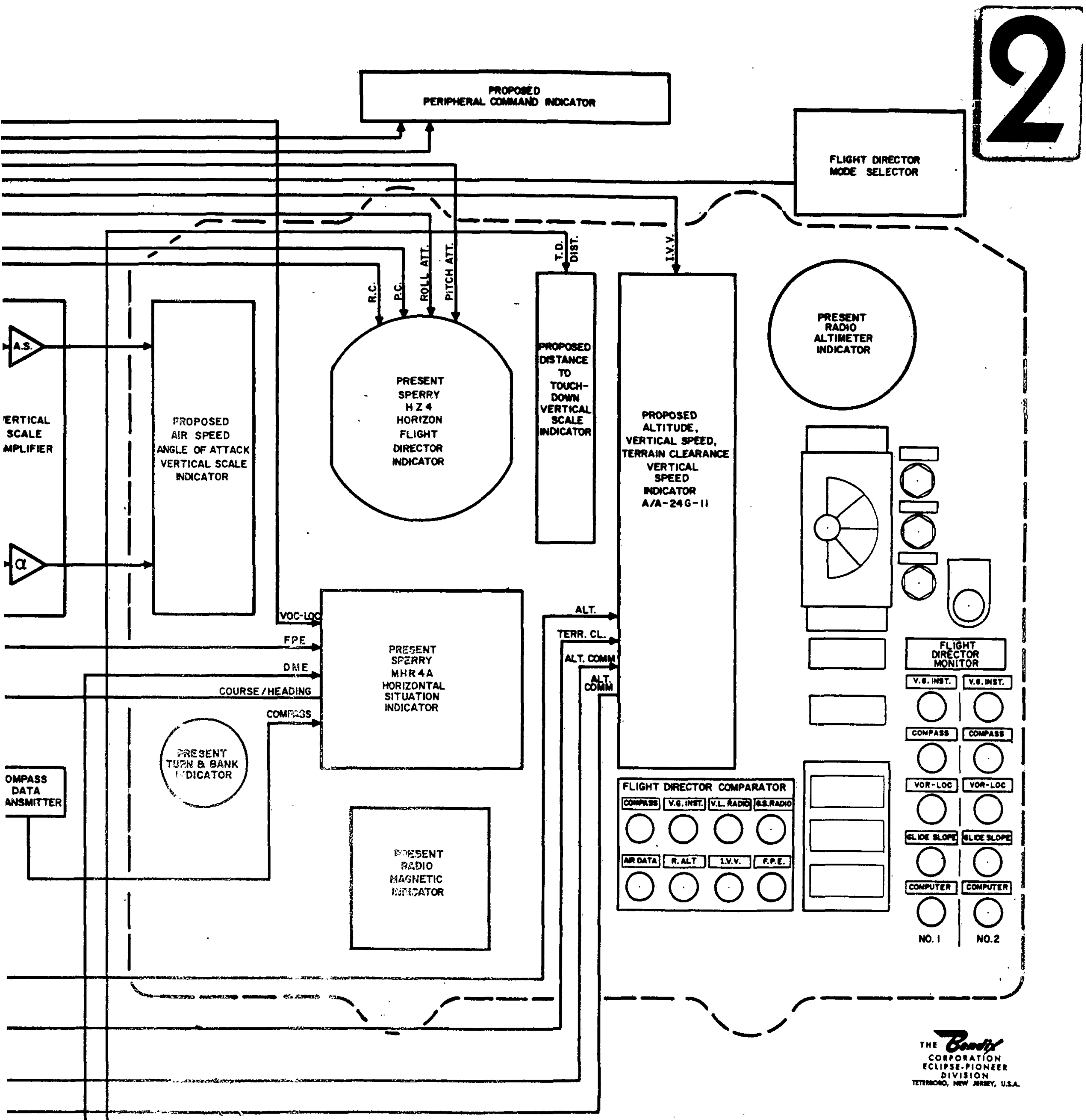

SENSOR INTERCONNECTION OF FIGURE 2 PANEL

FIGURE-2A

The single installation block diagram for Configuration #2 is shown in Figure 2A. The Central Air Data provides the inputs for display on the Vertical Scale Air Speed and Angle of Attack Indicator.

The interconnector for the other components are identical to that required for Configuration #1.

The components required for implementation of Configuration #2 is given in Table II.

TABLE II (Configuration #2)

PANEL

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
1) Present Rate of Turn Indicator						
2) Present Clock						
3) Present Horizon Flight Director Indicator HZ4						
4) Present Horizontal Situation Indicator (MHR4A)						
*5) Radio Magnetic Indicator 36135-C1	3.12x3.25x 5 3/32	2.5 lb	26V at 400~ 5 VA	$690.0	60-90 Days	E-P
*6) Distance to Touchdown Ind	1.25x5.875x 5.5	3 lb	115V 400~ 30 VA	$6000	5 month (estimate)	See Text
*7) Vertical Speed, Altitude, Terrain Clearance V/S Indicator	3x10 1/2x 8 1/2	10.5 lb	Supplied by V/S Amp.	$32,618. includes amplifier	5 Months ARC	Mil-A-27671
8) Present Radio Altitude Ind.						
9) Present Bleu Phase Ind.						
10) Flight Director Phase Indicator	1.6875x3.5 x2.0	75 lbs	supplied by IVV Aug GS and Flare Coupler	$100	1 month (estimate)	See Text

TABLE II (Configuration #2) (Cont'd)

PANEL

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
*11) Flight Director Comparator Lamps	Position as shown		Supplied by monitor-comparator	$200	1 month (estimate)	
*12) Flight Director Monitor Lamps	Panel layout		Supplied by warning system	$200	1 month (estimate)	
*13) Peripheral Comm Indicator (above panel)	8 1/4"x 1 3/8"x 3 1/2"	3 lbs	←	not available as of 12-12-62		→
*14) Mode Selector Switch (above panel)				$245	3 months (estimate)	
*15) SCAT fast-slow Indicator (above panel)	3.10x1.3x 2.83	.4 lb	5V at .3 Amp (lamps)	included with SCAT system price	90 day ARO	
*16) Airspeed-Angle of Attack V/S Indicator (EP would propose)	2.25x8x9	7 lb	Supplied by V/S amplifier	$12,000. includes amplfs.	6 months ARO	Similar to Mil-A-27670 See Text

TABLE II

ASSOCIATED EQUIPMENT

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
*1) SCAT System a) Lift Transducer 775 b) Flap Transmitter 925 c) Summing Unit 01AB03	3 5/8Dx4 15/16 2.06x2.7x3.65 9 1/8x8x12 3/4	1 lb 20 lb	115V ac at 4 amp 28V dc 1 amp 26V ac 1 amp System requirements	$10,693.80 system price (includes indicator)	90 day ARO 120 day ARO 150 day ARO	
2) Present VOR-LOC Radio						
3) Present Glide Slope Radio						
4) Present Vertical Gyro						
5) Present Distance measuring Equipment						
*6) Monitor-Comparator Coupler	3/4 ATR Short	12 lb	115V ac 400~ 70 VA 28V dc 40W	$23,000	6 Mo.	See Text
7) Present Flight Dir Computer Z5						
*8) Central Air Data Computer CPU/43A	1/2 ATR long	24 lb	115V at 400~ 47 VA	$17,000.	7 Mo. ARO	Arinc 545
*9) IVV, Aug. GS and Flare Module	3/4 ATR short	15 lb	115V at 400~ 100 VA 28V dc 14 Watts	$28,000	6 Mo.	See Text

TABLE II (Cont'd)

ASSOCIATED EQUIPMENT

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
*10) Radar Altitude FAA proposed	729 cu. in (Max.)	15 lb	115V at 400~ 28V dc			FAA ltr #58
*11) Vert. Speed Altitude and Terrain V/S amplifier	4 7/16x4 1/2 x 10 29/32	8 lb	115V at 400~ 63 VA	included with indicator		Mil-A-27671
12) Present rate of Turn Sensor						
13) Present C4A Compass						
14) Present Flight Dir. Amplifier						
15) Present RMI Amplifier						
*16) Peripheral Comm and Coupler		Information	not available on	requirements $600	for coupler	
*17) Airspeed/Angle of attack/ampl. (EP would propose)	4x4 1/2x 6 1/4	6 lb	115V ac 50 VA	included with instrument	6 mo ARO	similar to mil-A-27670

Electrical Load Analysis - The following estimate is based on a single installation as shown in Figure 2A and reflects only the additional power required for the proposed system.

115 Volts at 400 Cycles	- 975 VA
26 Volts at 400 Cycles	- 120 VA
28 Volts DC	- 45 VA

Conclusions With Regard to Configuration #2 - The conclusions stated for Configuration #1 generally apply to Configuration #2 since the only difference is in the Round Dial verses Vertical Scale Display of Airspeed-Angle of Attack.

The Vertical Scale Display of Airspeed does provide more complete inherent monitoring features than the standard round dial airspeed indicator.

In addition, the panel layout affords the present day emphasis on Vertical Scale displays.

2.3 Configuration #3

This panel configuration is shown in Figure 3. The instrumentation consists of the following units:

1. Presently installed Airspeed Indicator.
2. Presently installed Angle of Attack Indicator
3. Clock
4. C6-A Gyrosyn Compass Indicator
5. Attitude Direction Indicator ARU-2 B/A
6. Horizontal Situation Indicator AQU-4/A, modified to incorporate Distance Analog Tape
7. RMI (E-P 36135)
8. Vertical Scale Display of Vertical Speed, Altitude, and Terrain Clearance
9. Presently installed Radio Altimeter
10. Bleu Auto-Land Phase Indicator
11. Flight Director Phase Indicator
12. Flight Director Comparator and Warning Lights

*13. Peripheral Command Indicator, Fast-Slow Indicator and Mode Selector Switch

* Located above Panel

The airspeed and angle of attack instruments are retained and operate as presently installed

The C6-A Gyrosyn Compass Indicator (Sperry) is required to provide compass synchronizations with the presently installed Sperry C4-A Compass System. This requirement was mentioned in Progress Report #2 (September 15, 1962). The data transmitter in the C6-A provides primary heading information to the Horizontal Situation Indicator while the RMI, below the HSI, receives heading from the co-pilot's Master Heading Reference Indicator - thus, heading from two separate sources is presented to the pilot on the HSI and RMI.

The Attitude Director Indicator is the unmodified ARU-2 B/A, i.e., the flight path angle servoed tape is not included. There does not appear to be justification to display flight path angles on this indicator since ground speed corrections to the air derived flight path angle would have to be provided to enable the flight path angle to serve as a monitor for the glide slope beam. The complexity and cost of such compensation in addition to the increased cost of the instrument itself was the deciding factor in recommending the standard A. D. I. (no tape).

The instrument displays roll and pitch altitude, roll and pitch command, rate of turn, glide slope error and contains an inclinometer.

Since rate of turn is displayed on this instrument, the presently installed Rate of Turn Indicator was removed.

The signals feeding the attitude and command displays are supplied from the Vertical Gyro and Flight Director Computer shown in Figure 3A.

The servo amplifiers which position the altitude sphere are integrally contained within the indicator. It must be noted that pitch and roll attitude bootstraps are not available in this unit.

The Horizontal Situation Indicator shown in Figure 3 is an AQU-4/A, modified to include an analog distance display. The salient features presented on this indicator are: heading, VOR/TACAN bearing, a digital (Counter) and analog display of TACAN Range (distance), VOR-LOC deviation and provision for selection of heading and course signals for use with a Flight Director or Autopilot Computer. In addition, pre-select heading and pre-select course can be remotely selected. The five servo amplifiers required for heading, bearing, analog distance display, pre-select heading, pre-select course are self contained.

The pre-select course can be read on a counter at the upper right of the instrument.

The RMI (36135), Vertical Scale display of vertical speed, terrain clearance and barometric altitude, radio altimeter, phase indicators and warning lights have been previously described.

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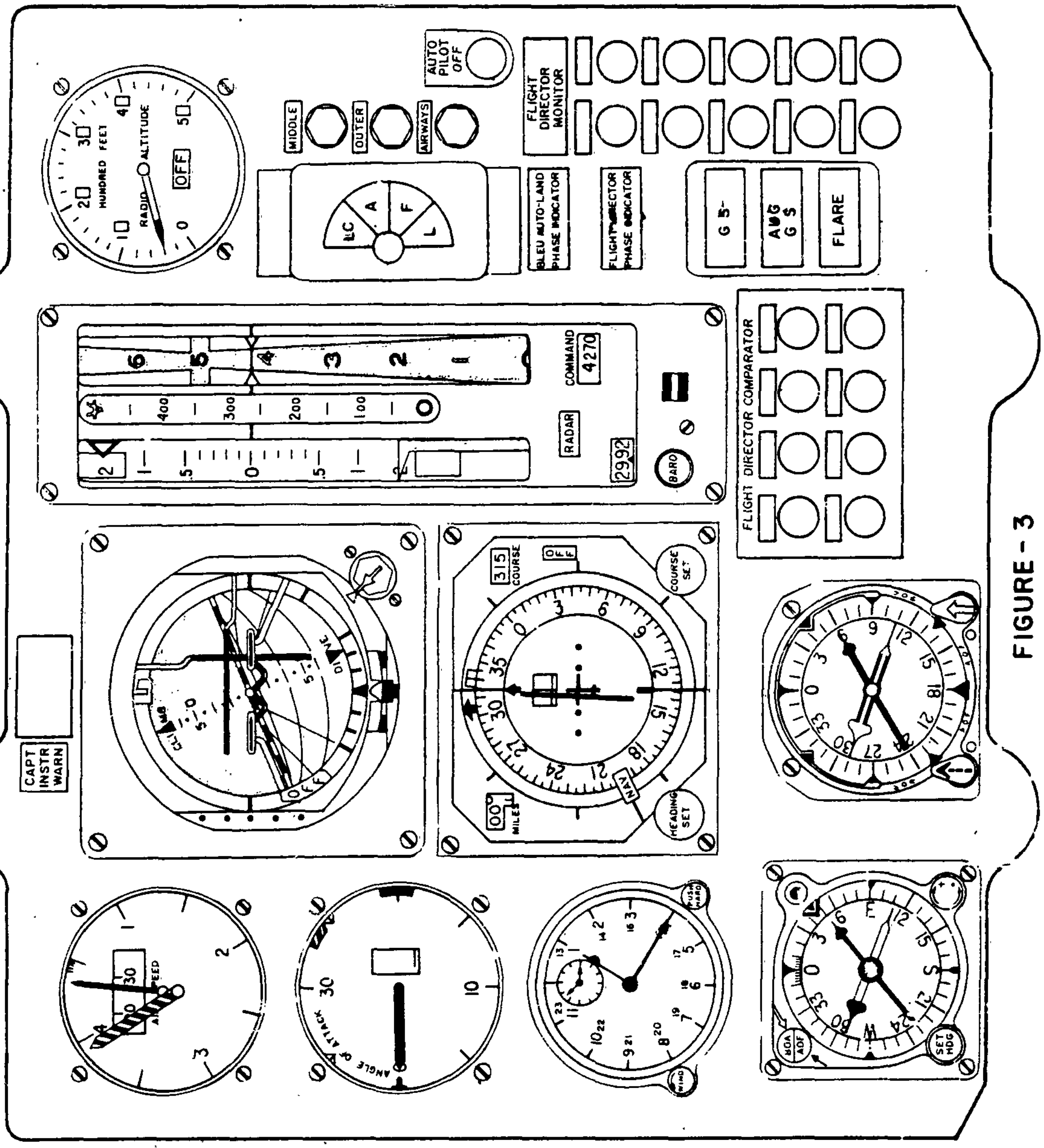
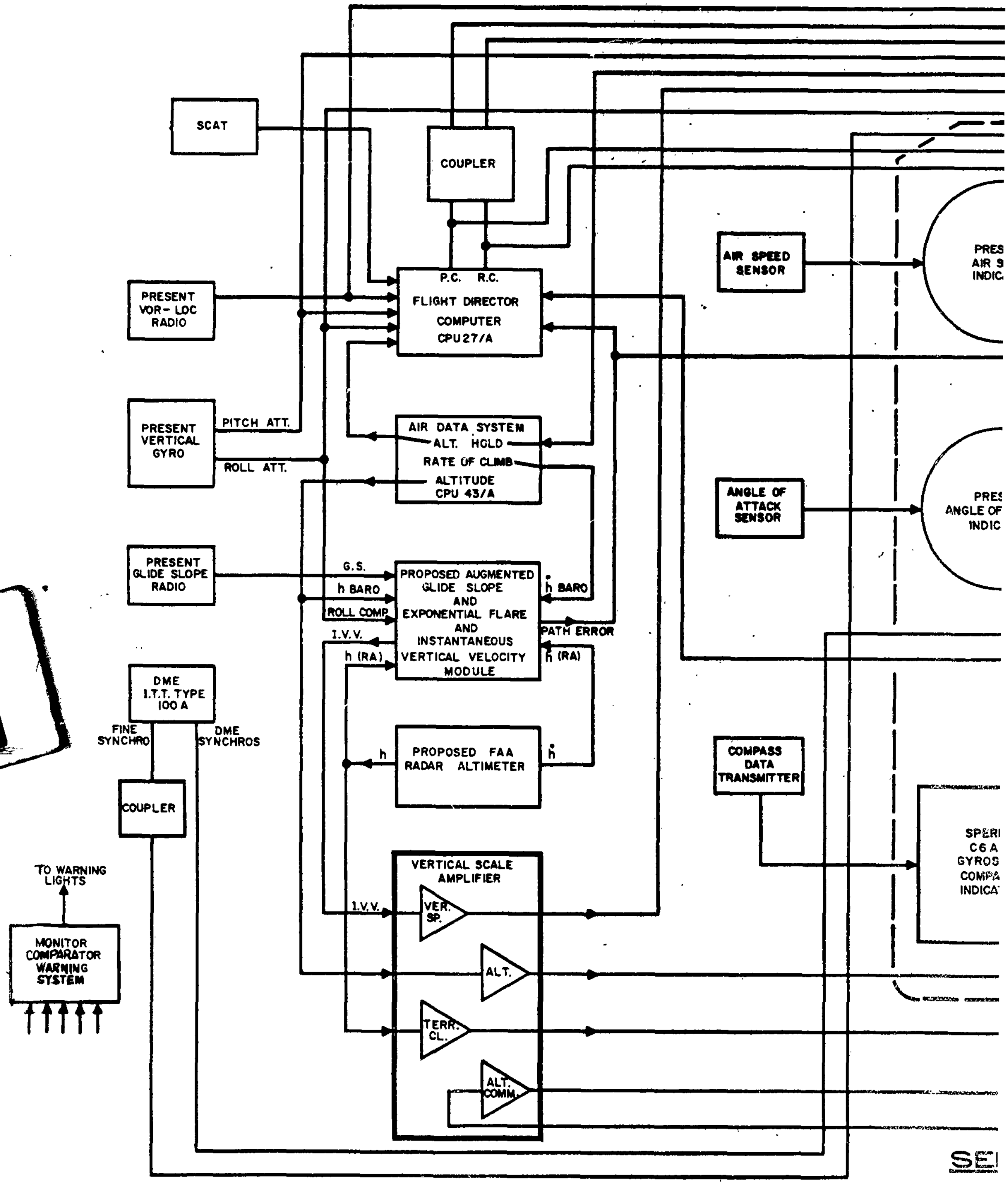


FIGURE - 3

1


SCAT
COUPLER
P.C. R.C.
FLIGHT DIRECTOR
COMPUTER
CPU 27/A
PRESENT
VOR-LOC
RADIO
PRESENT
VERTICAL
GYRO
PITCH ATT.
ROLL ATT.
AIR DATA SYSTEM
ALT. HOLD
RATE OF CLIMB
ALTITUDE
CPU 43/A
PRESENT
GLIDE SLOPE
RADIO
G.S.
h BARO
ROLL COMP.
I.V.V.
h (RA)
PROPOSED AUGMENTED
GLIDE SLOPE
AND
EXPONENTIAL FLARE
AND
INSTANTANEOUS
VERTICAL VELOCITY
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I.T.T. TYPE
100 A
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SYNCHRO
DME
SYNCHROS
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PROPOSED FAA
RADAR ALTIMETER
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TO WARNING
LIGHTS
MONITOR
COMPARATOR
WARNING
SYSTEM
VERTICAL SCALE
AMPLIFIER
I.V.V.
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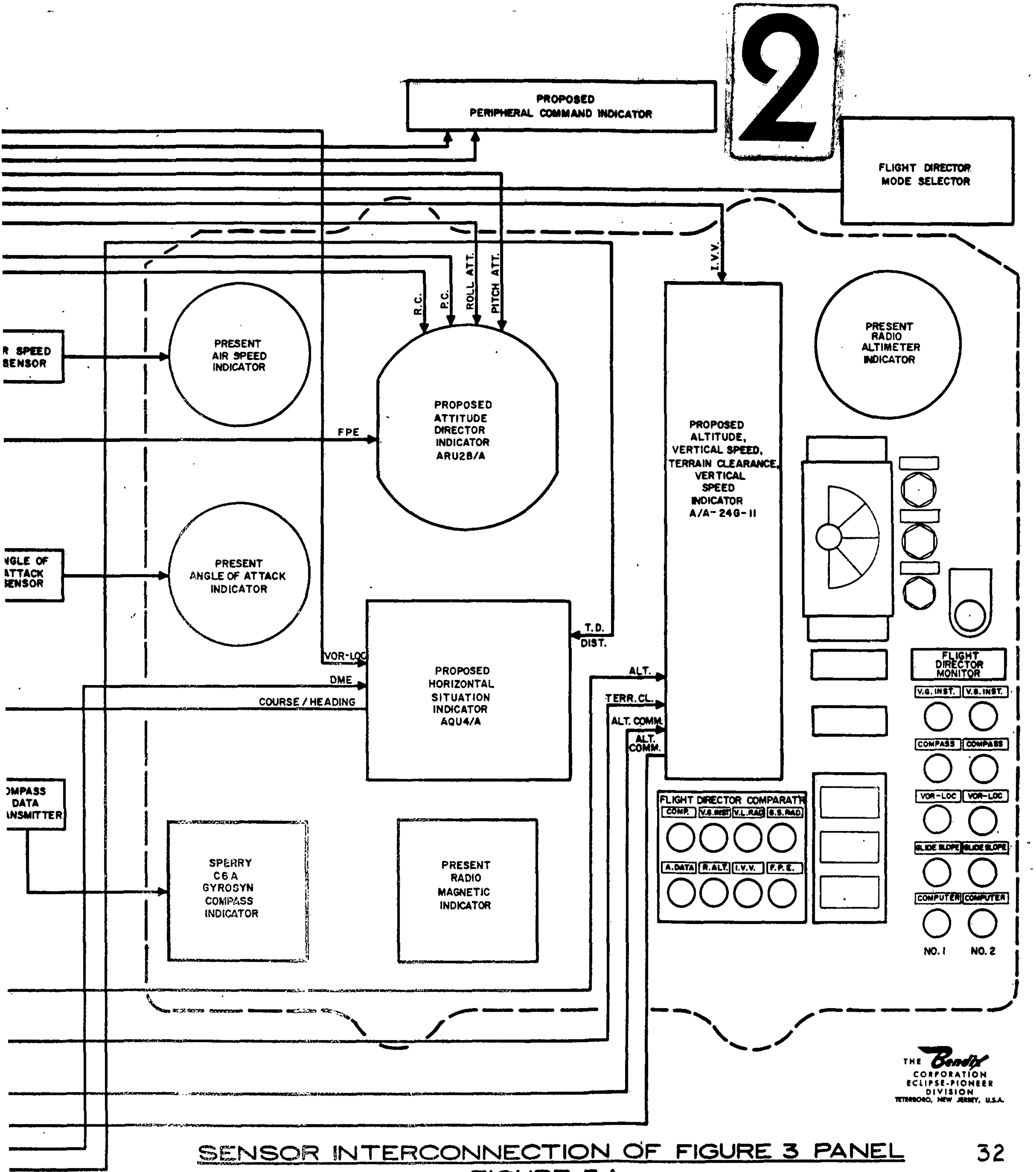

SENSOR INTERCONNECTION OF FIGURE 3 PANEL

FIGURE 3A

The block diagram of the single installation associated with Configuration #3 is shown in Figure 3A. It is not felt necessary to describe the entire signal flow since it is similar to the description included for Figure 1A, but only the differences in the remote electronics required.

It is shown in Figure 3A that the Flight Director Computer proposed is the CPU 27/A rather than the presently installed Z-5 Computer. The CPU-27/A is the most recent flight director computer specified by the Air Force and, in addition to containing circuitry for more diversified missions, also contains the D. C. power output required to drive the roll and pitch command meter movements. The CPU-27A is especially recommended when integration with the Attitude Director Indicator ARU-2B/A is required.

It is also seen that the addition of a coupler between the DME (ITT 100A) fine synchro output and the distance analog tape is required. This provision is necessary to convert the A. C. signal from the fine synchro to an appropriate DC signal required to drive the distance analog tape in the Horizontal Situation Indicator.

A Table of Contents is given below listing the components required for implementation of the proposed Configuration #3. The listing reflects components for a <u>single</u> installation.

TABLE III (Configuration #3)

PANEL

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
1) Present Airspeed Indicator						
2) Present Angle of Attack Indicator						
3) Present Clock						
*4) Attitude Director Indicator ARU2B/A (no tape) (Lear)	5x5.25x9.1		115V 400 ~ at .4 Amp	$3, 400.0	180 day ARO	ASNPF 62-22
*5) Horizontal Situation Ind. AQU4A/ modified with distance analog tape(Collins)	5x4.25x8	8.5 lb	5V at .7 Amp 115V at .4 Amp	$9, 931.0	6 month	similar to Mil-H-27848
*6) Compass Ind. C6A (Sperry)	3 9/32x39/32 x10 15/32	4 lb	5V at 1.2 amp 26V at .9 amp	$1458.00	1 month	Sperry
*7) Radio Magnetic Indicator 36135-CI	3.125x3.25x 5 3/32	2.5 lb	26V 400 cps 5VA	$690.00	60-90 days	E-P
*8) Vertical Speed Altitude, terrain clearance V/S indicator	3x10 1/2x 8 1/2	10 1/2 lb	Supplied by V/S Ampl	$32, 618 Includes Ampl.	5 months ARO	Mil-A-27671
9) Present Radio Altitude Indicator						

TABLE III (Configuration #3) (Cont'd)

PANEL

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
10) Present Bleu Phase Indicator						
*11) Flight Director Phase Indicator	1.6875x3.5x2	3/4 lb	Supplied by IVV Aug GS and Flare Coupler	$100	1 month (estimate)	See Text
*12) Flight Director Comparator Lamps	position as shown on panel layout		Supplied by Monitor-Comparator Warn system	$200	1 month (estimate)	See Text
*13) Flight Director Monitor Lamps	Position as shown		supplied by warning system	$200	1 month (estimate)	
*14) Peripheral Command FD (above panel)	8 1/4x1 3/8" x 3 1/2"	3 lbs	not available as of 12-12-62			
*15) Mode Selector Switch (above panel)				$245	3 month (estimate)	
*16) SCAT fast-slow indicator (above panel) Safe-Flite	3.1"x1.3"x 2.83"	.4 lb	5V at .3 amp (lamps)	Included with SCAT system price	90 day ARO	

TABLE III

ASSOCIATED EQUIPMENT

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
*1) SCAT System a) Lift Transducer 775 b) Flap Transmitter 925 c) Summing Unit 01AB03	3 5/8D x 4 15/16 2.06x2.7x3.65" 9 1/8"x8"x 12 3/4"	1 lb 20 lb	115V at 4A 28V dc 1A 26Vac at 1A System requirements	$10, 693.80 system price (includes indicator)	90 days ARO 120 days ARO 150 days ARO	
2) Present VOR-LOC						
3) Present GS Radio						
4) Present V.G.						
5) Present DME						
*6) Monitor-Comp Coupler (EP would propose)	3/4 ATR short	12 lb	115V ac 400 cps 70VA 28V dc 40 Watts	$23, 000	6 month	See Text
*7) Flight Dir. Comp. CPU 27A	5 1/2x7 13/16 x 9 5/8	12 lb	115V ac 16VA 28Vdc 13W	$1, 367.00	6 month	Mil-C-27522
*8) Central Air Data Computer CPU/43A	1/2 ATR long	24 lb	115Vac 47VA	$17, 000.00	7 month ARO	ARINC 545
*9) IVV, Aug GS, Flare Coupler	3/4 ATR Short	15 lb	115V 400~ 100VA 28Vdc 14 Watts	$28, 000	6 month	See Text

TABLE III (Cont'd)

ASSOCIATED EQUIPMENT

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
*10) Radar Altitude FAA proposed	729 cu. in	15 lb	115V 400~ 28 V dc			FAA ltr #58
*11) Vertical Speed altitude and terrain clear. V/S Ampl	4 7/16"x4 1/2" x10 29/32	8 lb	115V ac 63VA	included with indicator		Mil-A-27671
12) Present Air Speed sensor						
13) Present angle of attack sensor						
14) Present Rate of turn sensor						
15) Present C4-A Compass						
16) Present RMI Amplifier						
*17) Distance to TD Coupler	1/4 ATR short	3 lb	115V 400cps 35VA	$900		
*18) Peripheral Command Coupler	← Information not available on requirements for coupler →			$600		

Electrical Load Analysis - The following estimate is based on the single installation as shown in Figure 3A and reflects only the additional power required for the proposed system.

115 Volts 400 cycles	- 1000 VA
26 Volts 400 cycles	- 120 VA
28 Volts DC	- 45 VA

Conclusions With Regard to Configuration #3 - The obvious advantage in selection of the 5 inch Attitude Director Indicator is in its size. It is difficult to evaluate as to how much is gained from the larger display. However, it is certainly recommended that this type of display be considered for the instrument panel.

The Horizontal Situation Indicator has one very important feature related to the All-Weather Landing Program. This is the analog presentation of distance to touchdown. The picture presented to the pilot not only shows him distance in a manner that is more easily interpreted in the landing phase than that presented on the digital (counter) display, but also provides a pictorial representation of the crab angle prevalent in flight. The localizer bar and analog distance display will alert the pilot to any de-crabbing required near touchdown.

If a discrepancy exists in this distance display, it is the small excursion representing the final three miles from touchdown.

The comments for the remainder of the panel are reflected in the conclusions with regard to Configuration #1.

There does not appear to be a requirement to make use of the remote selection feature available in the Horizontal Situation Indicator with regard to Pre-Select Heading and Course. However, if it is decided that this should be used, this addition of the appropriate control box for remote selection of this feature can easily be included.

2.4 Configuration #4

This panel configuration is shown in Figure 4. The panel is similar to that proposed in Figure 3 with the exception that the round dial angle of attack and airspeed indicators are replaced with vertical scale displays of same.

It is not felt necessary to again comment on the salient features of the Vertical Scale Airspeed-Angle of Attack Indicator.

Since it was also thought that a review of the signal flow for Configuration #4 was not necessary, Figure 4A has not been included in this report.

A Table of Contents is given below listing the components required for implementation of the proposed Configuration #4 Instrument Panel and associated sensors and couplers.

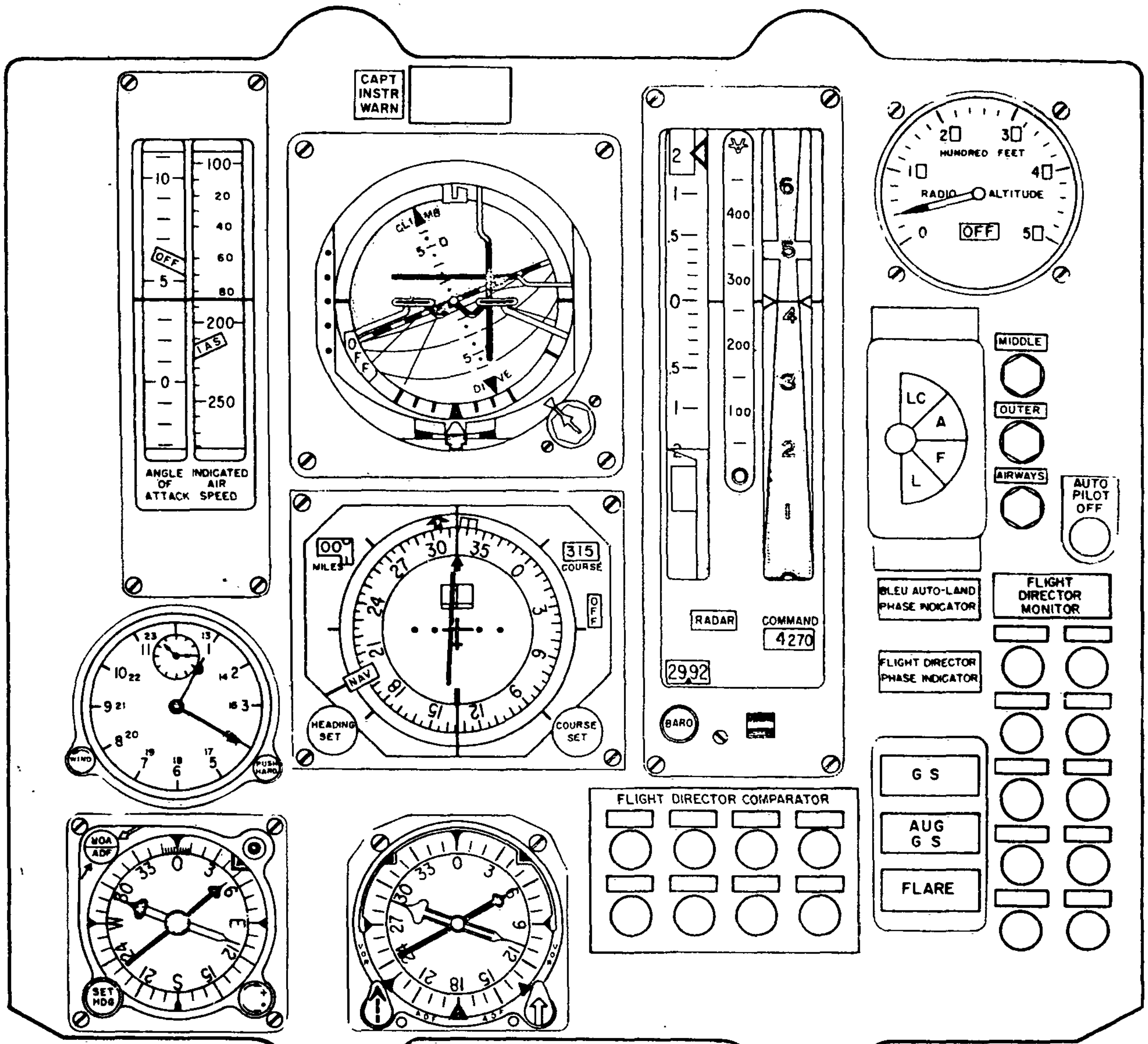

FIGURE-4

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TABLE IV (Configuration #4)

PANEL

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
1) Present Clock						
*2) Attitude Director Indicator (no type) ARU2B/A (Lear)	5x5.25x9.1		115V 400~ .4 Ampt	$3, 400.00	180 day ARO	ASNPF 62-22
*3) Horizontal Situation Indicator AQU 4A/modified with distance analog tape (Collins)	5x4.25x8	8.5 lb	5V at .7 amp 115V at .4 amp	$9, 931.00	6 month	similar to Mil-H-27848
*4) Compass Ind. C6A	39/32 Sqx 10 15/32	4 lb	5V at 1.2 amp 26V at .9 amp	$1, 458.00	1 month	Sperry
*5) Radio Magnetic indicator 36135-C1	3.125x3.25x 5 3/32	2.5 lb	26V ac 400cps 5VA	$690.00	60-90 days	E-P
*6) Vert. Speed, Altitude Terr. Clear, V/S Indicator	3x10 1/2x 8 1/2	10.5 lb	Supplied by V/S Amplifier	$32, 618.00 includes amplifier	5 month ARO	MIL-A-27671
7) Present Radio Altitude Ind.						
8) Present Bleu Phase Ind.						
*9) Flight Dir. Phase Ind	1.6875x3.5 x2	3/4 lb	Supplied by IVV Aug GS and Flare Coupler	$100	1 month (estimate)	See Text
*10) Flight Dir. Comparator Lamps	Position as shown on panel layout		Supplied by Monitor-Comparator Warn system	$200		

TABLE IV (Configuration #4) (Cont' d)

PANEL

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
*11) Flight Director Monitor lamps	Position as shown		Supplied by Warning system	$200	1 month (estimate)	
*12) Peripheral Command Ind. (above panel)	8 1/4x1 3/8 x 3 1/2	3 lbs	Not available as of 12-12-62			
*13) Mode Selector Switch (above panel)				$245	3 month (estimate)	
*14) SCAT fast-slow Ind. (above panel)	3.1x1.3x2.83	14 lb	5V at .3 Amp	Included with SCAT system price	90 day ARO	
*15) Airspeed, angle of attack V/S Indicator	2.25x8x9	7 lb	Supplied by V/S ampl.	$12, 000. 00	6 month ARO	Similar to Mil-A-27670 See Text

TABLE IV

ASSOCIATED EQUIPMENT

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
*1) SCAT System a) Lift Transducer 775	3 5/8D.x4 15/16	1 lb	115V at 4 amps 28V dc 1 amp 26V ac at 1 amp (system requirements)	$10,693.80/ System Price (includes indicator)	90 Day	
b) Flap transmitter 925	2.06x2.7x3.65				120 Day	
c) Summing Unit 01AB03	9 1/8x8x12 3/4	20 lb			150 day	
2) Present VOR-LOC						
3) Present GS Radio						
4) Present V.G.						
5) Present DME						
*6) Monitor-Comparator Coupler	3/4 ATR Short	12 lb	115Vac 400cps 70VA 28V dc 40 Watts	$23,000	6 mo	See Text
*7) Flight Dir. Computer CPU27A	5 1/2x7 12/16 x9 5/8	12 lb	115V 16 VA 28V dc 13 Watt	$1,367.00	6 mo	Mil-C-27522
*8) Central Air Data Computer CPU/43A	1/2 ATR Long	24 lb	115V 47VA	$17,000.0	7 mo ARO	ARINC 545
*9) IVV Aug GS Flare coupler	3/4 ATR Short	15 lb	115V 400~ 100 VA 28V DC 14 Watts	$28,000	6 mo	See Text

TABLE IV (Cont'd)

ASSOCIATED EQUIPMENT

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
*10) Radar Altimeter FAA proposed	729 cu. in.	15 lb	115V 400~ 28 Vdc			FAA ltr #58
*11) Vert. Speed. Altitude and Terr. Clear V/S amplifier	4 7/16x4 1/2 x10 29/32	8 lb	115V 63VA	Included with Ind.		Mil-A-27671
12) Present Rate of Turn sensor						
13) Present C4A Compass						
14) Present RMI amplifier						
*15) Distance to TD coupler	1/4 ATR Short	3 lb	115V 400cps 35 VA	$900		
*16) Peripheral Command	Information not available on requirements for coupler			$600		
*17) Airspeed and angle of attack V/s Ampl.	4x4 1/2x6 1/4	6 lb	115V 50 VA	Included with Ind.	6 mo	similar to Mil-A-27670

Electrical Load Analysis - The additional power required is approximately the same as that required for Configuration #3.

Conclusions - The conclusions with regard to Configuration #4 are essentially those reflected for Configuration #3 in addition to the comments previously mentioned concerning the Vertical Scale dis play of Air Speed - Angle of Attack.

2.5 Configuration #5

This panel configuration is shown in Figure 5. The layout is identical to Configuration #1 with the exception that the HZ-4 Horizon Director Indicator has been replaced with a Bendix Horizon Director Indicator.

The Horizon Director Indicator (Bendix) provides the following salient features:

1. Roll and Pitch Attitude
2. Roll and Pitch Command on a single command bar
3. Speed Control (Slow-Fast)
4. The longitudinal mode displayed on the command bar. (Altitude, SCAT, Glide Slope, Augmented Glide Slope).

A brightness control is located in the lower right corner of the instrument. This allows for adjustment of the light intensity supplied to the four mode indicators.

The block diagram of the single installation associated with Configuration #5 is shown in Figure 5A.

The only basic difference in the couplers for this configuration as compared to Configuration #1 is the use of the Bendix (300 Series) Flight Director Computer and Flight Instrument Amplifier.

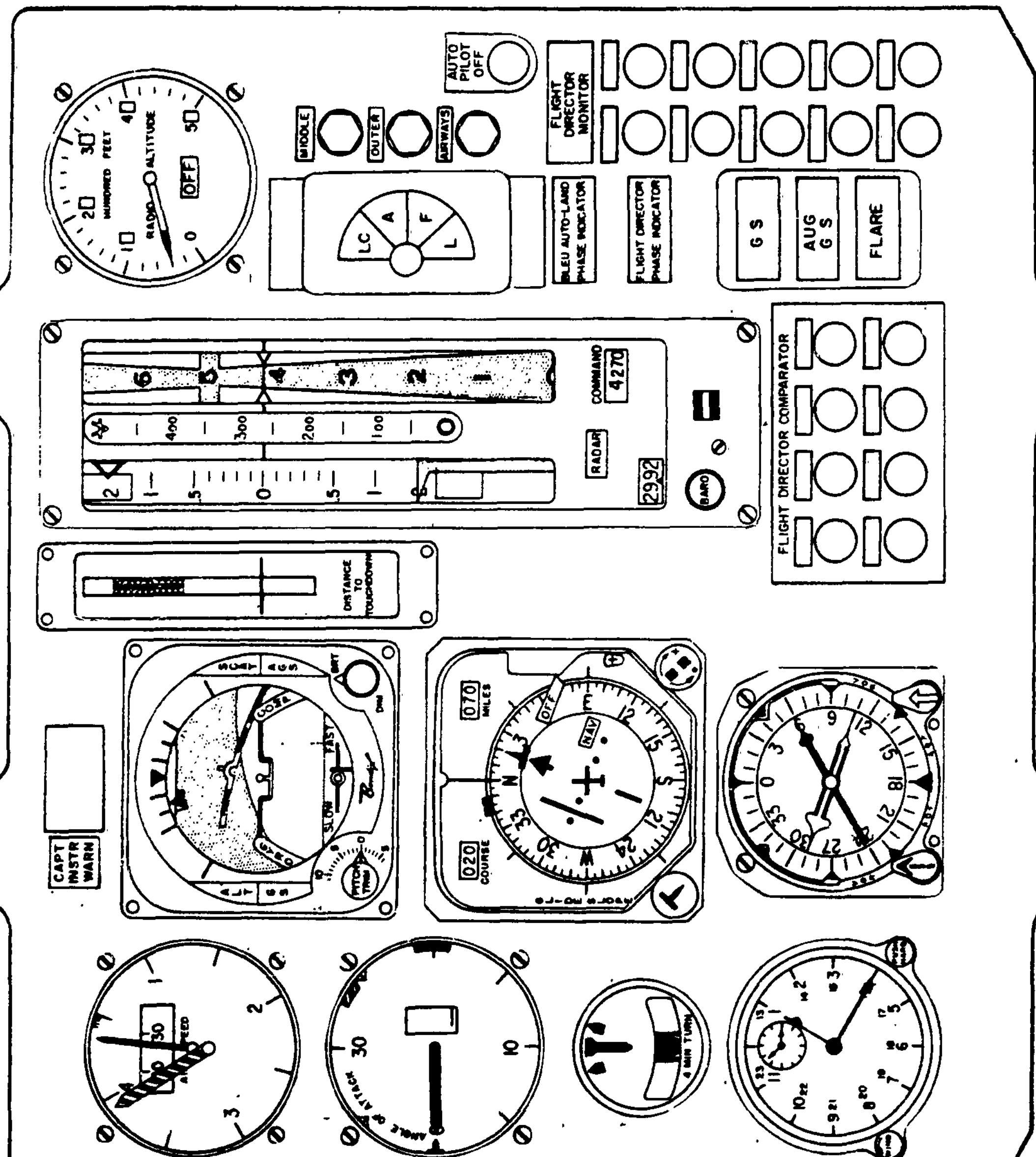
The computer outputs (Roll and Pitch Command) are 400 cycle signals required to drive the Roll and Pitch Command Servo Amplifiers.

If it is desired to retain the HZ-5 Computer (DC outputs), a coupler could be added to provide the appropriate scaling for integration with the referenced Horizon Director Indicator.

The Flight Instrument Amplifier is required since the command bar is servo driven rather than DC meter movements.

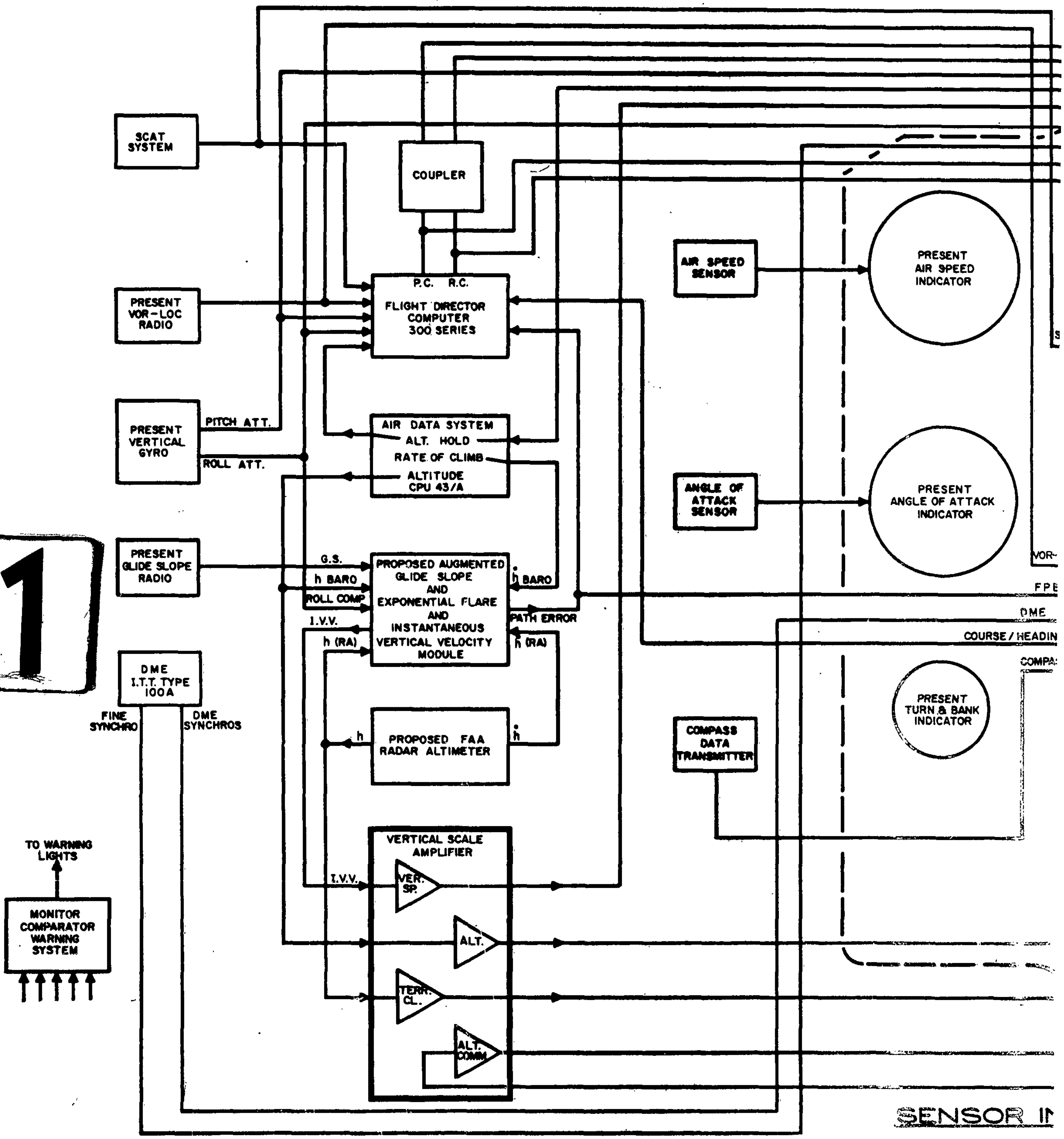
This Horizon Director Indicator is similar to the Bendix Production Type 17810 Horizon Director Indicator but has been up-dated to display speed commands and mode indications to meet the requirements for a more integrated display for lower minimums.

A Table of Contents is given below listing the components required for implementation of the proposed Configuration #5. This listing reflects components for a single installation.



AUTO PILOT OFF
FLIGHT DIRECTOR MONITOR
MIDDLE
OUTER
AIRWAYS
HUNDRED FEET
RADIO ALTITUDE
OFF
LC
A
F
L
BLEU AUTO-LAND PHASE INDICATOR
FLIGHT DIRECTOR PHASE INDICATOR
G S
AUG G S
FLARE
COMMAND
4270
RADAR
2992
BARO
FLIGHT DIRECTOR COMPARATOR
DISTANCE TO TOUCHDOWN
CAPT INSTR WARN
FAST
SLOW
PITCH TRIM
070
MILES
020
COURSE
NAV
OFF
AIRSPEED
ANGLE OF ATTACK
4 MIN TURN

FIGURE-5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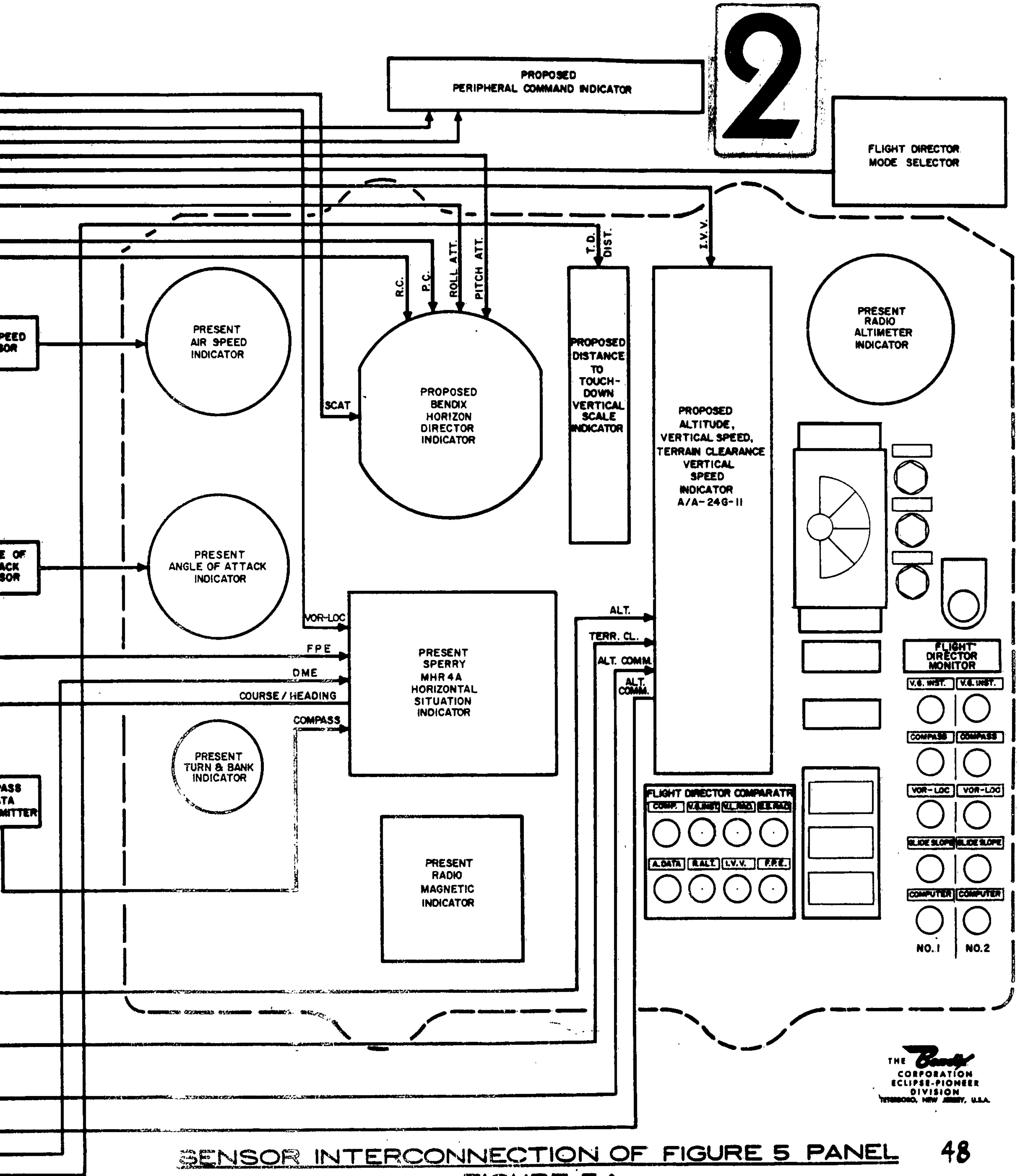
COUPLER
PRESENT VOR-LOC RADIO
P.C.
R.C.
FLIGHT DIRECTOR COMPUTER 300 SERIES
PRESENT VERTICAL GYRO
PITCH ATT.
ROLL ATT.
AIR DATA SYSTEM
ALT. HOLD
RATE OF CLIMB
ALTITUDE CPU 43/A
PRESENT GLIDE SLOPE RADIO
G.S.
h BARO
ROLL COMP
I.V.V.
h (RA)
PROPOSED AUGMENTED GLIDE SLOPE AND EXPONENTIAL FLARE AND INSTANTANEOUS VERTICAL VELOCITY MODULE
ḣ BARO
PATH ERROR
ḣ (RA)
DME I.T.T. TYPE 100A
FINE SYNCHRO
DME SYNCHROS
h
PROPOSED FAA RADAR ALTIMETER
ḣ
TO WARNING LIGHTS
MONITOR COMPARATOR WARNING SYSTEM
VERTICAL SCALE AMPLIFIER
I.V.V.
VER. SP.
ALT.
TERR. CL.
ALT. COMM
AIR SPEED SENSOR
PRESENT AIR SPEED INDICATOR
ANGLE OF ATTACK SENSOR
PRESENT ANGLE OF ATTACK INDICATOR
COMPASS DATA TRANSMITTER
PRESENT TURN & BANK INDICATOR
VOR-
FPE
DME
COURSE / HEADIN
COMPA

1

SENSOR IN



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SENSOR INTERCONNECTION OF FIGURE 5 PANEL

FIGURE 5A

TABLE V (Configuration #5)

PANEL

Component	Size	Weight	Power	Unit Cost	Delivery	
1) Present Airspeed Indicator						
2) Present Angle of Attack Indicator						
3) Present Clock						
4) Present Rate of Turn Indicator						
*5) Proposed Horizon and Director Indicator, (Bendix)	4x4x8.338		Supplied by Flight Instr. Amp.	$3000		Bendix
6) Present Horizontal Situation Indicator (MHR4A)						
*7) Proposed Magnetic Indicator 36135-C1	3.125x3.25 x5 3/32	2.5 lb.	26 Vac 400 cps 5 VA	$690.00	60-90 days	E-P
*8) Proposed distance to TD Indicator	1.25x5.87 x5.5	3 lb.	115 V 400 cps 30 VA	$6000	5 month (estimate)	
*9) Vert. Speed, Alt. Terrain Clear. Ind. (Vert. Scale)	3x10 1/2 x8 1/2	10.5 lb.	Supplied by V/S Amp.	$32,618 includes Amp.	5 month (ARO)	MIL-A-27671
10) Present Radio Altitude Ind.						

TABLE V (Configuration #5) Cont'd.

PANEL

Component	Size	Weight	Power	Unit Cost	Delivery	Spec.
11) Present Bleu Phase Indicator						
*12) Proposed FD Phase Indicator	1.6875x3.5x2	3/4 lb.	Supplied by IVV Aug GS and Flare Coupler	$100	1 month (estimate)	See Text
*13) FD Comp Lamps	Position as Shown On Panel Layout		Supplied by Monitor-Comparator Warn System	$200	1 month (estimate)	See Text
*14) FD Monitor Lamps				$200	1 month (est)	
*15) Peripheral Command Ind. (above panel)	8 1/4x1 3/8 x3 1/2	3 lbs.	← Not Available as of 12/12/62 →			
*16) Mode Selector Switch (above panel)				$245	3 month (estimate)	

TABLE V

ASSOCIATED EQUIPMENT

	Component	Size	Weight	Power	Unit Cost	Delivery	
*1)	SCAT System				$10,693.80 system		
2)	Present VOR-LOC Radio						
3)	Present GS Radio						
4)	Present V.G.						
*5)	Present DME						
*6)	Monitor Comp Coupler	3/4 ATR short	12 lb.	115Vac 70 VA 28Vdc 40 Watts	$23,000	6 months	See Text
*7)	F.D. Computer (Bendix P/N 16063)	3/4 ATR short	19 lb.	115V 400 cps 100 VA	$4, 500		
*8)	Central Air Data Computer CPU/43A	1/2 ATR long	24 lb.	115Vac 47 VA	$17,000.	7 months ARO	ARINC 545
*9)	IVV Aug GS Flare Coupler	3/4 ATR short	15 lb.	115V 400 cycles 100VA 28Vdc 14 W	$28,000		See Text
*10)	Radar Alt. F.A.A. Proposed	729 in.^{3}	15 lb.	115V 400 cycles 28Vdc			FAA Ltr. #58
*11)	Vert. Speed, Alt., and Terrain Clear. Vert. Scale Amp.	4 7/16x4 1/2 x10 29/32	8 lb.	115Vac 53 VA	Included with Ind.		MIL-A-27671
12)	Present Air Speed Sensor						

TABLE V (Cont'd.)

ASSOCIATED EQUIPMENT

Component	Size	Weight	Power	Unit Cost	Delivery	Spec.
13) Present Angle of Attack Sensor						
14) Present Rate of Turn Sensor						
15) Present C4-A Compass						
*16) Flight Inst. Amp. (Bendix P/N 15465)	3/8 ATR short	9 lb.	115 V 400 cps 90 VA	$2500		
17) Present RMI Amp.						
*18) Peripheral Comm. Coupler	← Information Not Available on Requirement for Coupler →			$600		

Electrical Load Analysis - The following estimate is based on the single installation as shown in Figure 5A and reflects only the additional power required for the proposed system.

115 Volts 400 Cycles	1050 VA
26 Volts 400 Cycles	120 VA
28 Volts DC	45 VA

Conclusion With Regard to Configuration #5

The proposal of the use of the Bendix Horizon Director Indicator rather than the present HZ-4 Horizon Director Indicator constitutes the only difference between Configuration #5 and that proposed in Configuration #1. It is therefore considered only necessary to comment on this one indicator as the conclusion for Configuration #1 apply generally to this panel layout.

The proposed Horizon Director Indicator offers the following desirable features.

1. Roll and Pitch Command is presented on one symbol rather than two cross pointers.

2. The command display is servo-driven rather than meter movements, thus providing a "closed loop" display. In addition to eliminating the problem areas usually associated with meter movements, the servoed display also lends itself more easily to monitoring techniques which are not readily adaptive to DC meter movements displays.

The incorporation of the fast-slow (air speed) feature directly on the flight director indicator is one more step towards integration of critical landing information on one indicator.

This fast-slow indication provides for monitoring of the pitch command displayed on the flight director in the "go-around" mode, in addition to providing airspeed commands during take-off and cruise. The output of the SCAT unit will be fed to this meter movement.

The mode indicator depicting the various inputs to the pitch axis of the flight director constantly remind the pilot of the selected/automatic mode of operation.

The normal sequencing of the mode lights would be as follows:

Altitude, if altitude hold is engaged, would be lit until the outer marker is approached. When the mode selector switch is turned to Glide Slope, the Glide Slope mode will light. When the automatic switching from Glide Slope to Augmented Glide Slope occurs, the AGS mode will light. In the event the Flight Director disconnect is pressed and SCAT is armed, the SCAT mode will light. Thus the incorporation of the mode indicators provides the pilot with a constant reminder of the mode selected manually or automatically for display on the Horizon Director Indicator. Although not shown, a "flare" mode could be easily added thus providing a complete crosscheck for the Flight Director Phase Indicator.

2.6 Configuration #6

The panel layout for Configuration #6 is shown in Figure 6.

It is seen that it is identical to Configuration #5, Figure 5, with the exception that airspeed-angle of attack is displayed on a vertical scale rather than the presently installed round dial instruments. It was not felt necessary to submit a block diagram for this installation since the inputs to the Air Speed-Angle of Attack Vertical Scale, for the Central Air Data Computer, have already been shown, Figure 2A.

A table of contents is given below listing the components required for implementation of the proposed Configuration #6. The listing reflects components for a single installation.

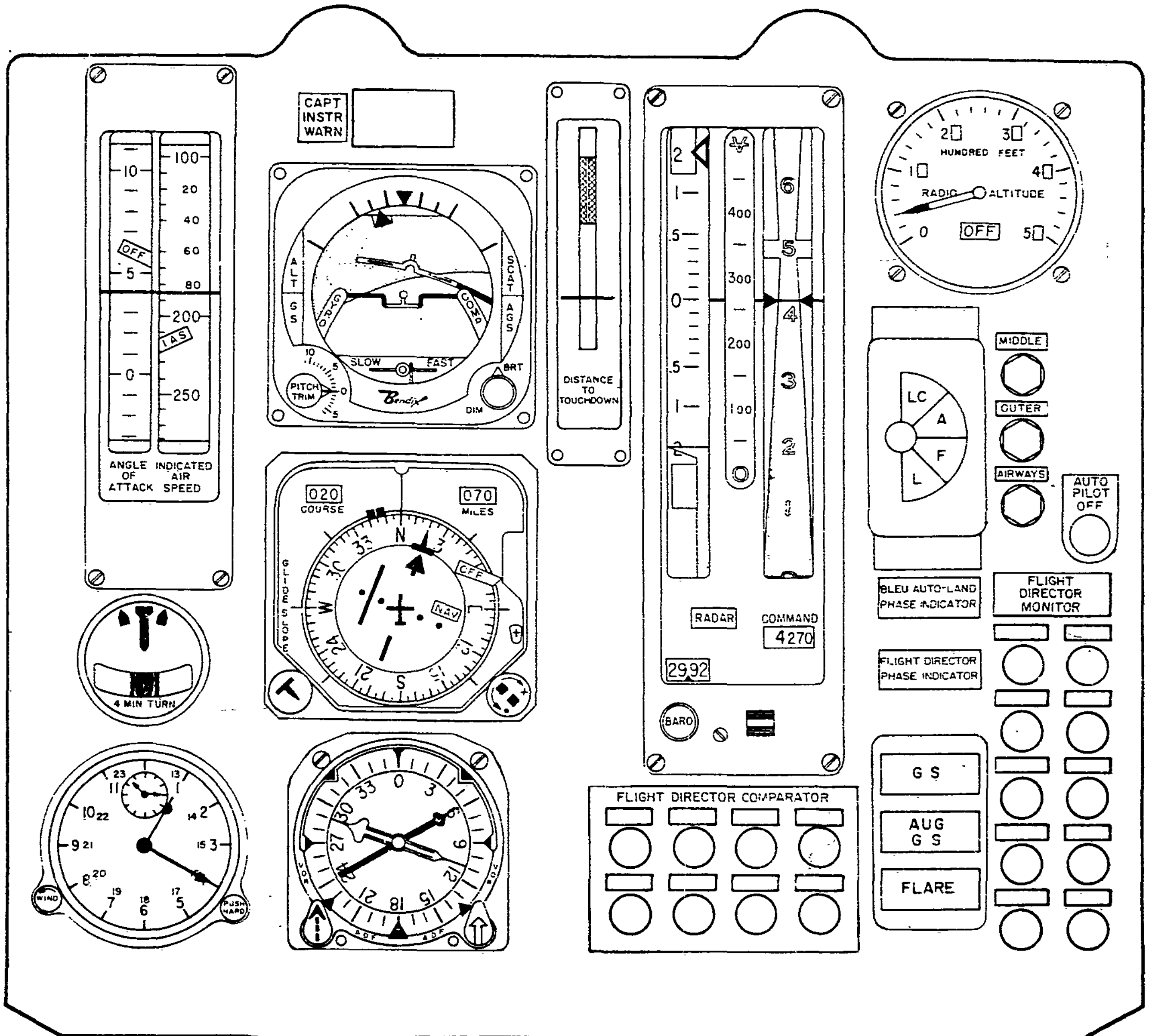

FIGURE 6

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TETERBORO, NEW JERSEY, U.S.A.

TABLE VI

PANEL

Component	Size	Weight	Power	Unit Cost	Delivery	Spec.
1) Present Clock						
2) Present Rate of Turn Indicator						
*3) Proposed Horizon and Director Ind. (Bendix)	4x4x8.338		Supplied by Flight Instr. Amp.	$3000		
4) Present Horizontal Situation Indicator (MHR4A)						
*5) RMI 36135	3.125x3.25x 5 3/32	2.5 lb.	26 Vac 400 cps 5 VA	$690.00	60-90 days	
*6) Proposed distance to TD Indicator	1.25x5.875 x5.5	3 lb.	115 V 400 cps 30 VA	$6000	5 month (estimate)	
*7) Vert. Speed, Alt. Terrain Clear., Vert. Scale Ind.	3x10 1/2x 8 1/2	10.5 lb.	Supplied by Vert. Scale Amp.	$32,618. Includes Amplifier	5 months ARO	MIL-A 27671
8) Present Radio Alt. Indicator						
9) Present Bleu Phase Indicator						
*10) Proposed FD Phase Indicator	1.6875x3.542	3/4 lb.	Supplied by IVV Aug GS and Flare Coupler	$100		See Text

TABLE VI (Cont'd.)

PANEL

Component	Size	Weight	Power	Unit Cost	Delivery	Spec.
*11) Proposed FD Comp Lamps	Position as Shown on Panel layout		Supplied by Monitor-Comparator Warn System	$200	1 month (estimate)	See Text
*12) Proposed FD Monitor Lamps	Position as shown		supplied by warning system	$200	1 month (estimate)	
*13) Proposed Peripheral Comm Indicator	8 1/4x1 3/8 x3 1/2	3 lbs.	Not Available as of 12-12-62			
*14) Mode Selector Switch (above panel)				$245	3 month (estimate)	
*15) Proposed Air Speed, Angle of Attack Vert. Scale Indicator	2.25x8x9	7 lbs.	Supplied by V/S Ampl.	$12,000. Group	6 months	Similar to MIL-A-27670

TABLE VI

ASSOCIATED EQUIPMENT

Component	Size	Weight	Power	Unit Cost	Delivery	Spec
*1) SCAT System						
a) Lift Transducer 775	3 5/8 Dia.x4 15/16	1 lb.	115Vac a 5A 28Vdc a 1A	$10,693.80 System Price includes Indicator.	90 day	
b) Flap Trans. 925	2.06x2.7x3.65		26Vac a 1A (System Require.)		120 day	
c) Summing Unit 01AB03	9 1/8x8x12 3/4	20 lb.			150 day	
2) Present VOR-LOC Radio						
3) Present GS Radio						
4) Present V.G.						
5) Present DME						
*6) Monitor Comp Coupler	3/4 ATR short	12 lb.	115Vac 70VA 28Vdc 40 Watts	$23,000	6 months	See Text
*7) Flight Director Computer (Bendix 16063	3/4 ATR short	19 lb.	115V 400 cps 100VA	$ 4,500		
*8) Central Air Data Computer CPU/43A	1/2 ATR long	24 lb.	115Vac 47 VA	$17,000.	7 months ARO	ARINC 545
*9) IVV Aug GS Flare Coupler	3/4 ATR Short	15 lb.	115V 400cycles 100VA, 28VDC, 14W	$23,000		See Text
*10) Radar Alt. F.A.A. Proposed	729 in.^{3}	15 lb.	115V 400 cycles 28Vdc			F.A.A. Ltr. #58

TABLE VI (Cont'd.)

ASSOCIATED EQUIPMENT

Component	Size	Weight	Power	Unit Cost	Delivery	Spec.
*11) Vert. Speed, Alt. and Terrain Clear. Vert. Scale Amplifier	4 7/16x4 1/2 x 10 29/32	8 lb.	115Vac 53 VA	Included with Indicator		MIL-A-27671
12) Present Rate of Turn Sensor						
13) Present C4-A Compass						
*14) Proposed Flight Instrument Amp. (Bendix P/N 15465)	3/8 ATR short	9 lb.	115V 400 cps 90 VA	$2500		
15) RMI Amplifier						
*16) Peripheral Command Coupler	< Information Not Available on Requirements for Coupler →			$600		
*17) Air Speed Angle of Attack Vert. Scale Amplifier	4x4 1/2 x 6 1/4	6 lb.	115V 50 VA	Included with Instrument	6 Months	Similar to MIL-A-27670

Electrical Load Analysis

The additional power required is approximately the same as that required for Configuration #5.

Conclusion With Regard to Configuration #6

The conclusion with regard to Configuration #6 are essentially those reflected for Configuration #5 in addition to the comments previously mentioned concerning the Vertical Scale display of Air Speed-Angle of Attack.

3. TYPICAL CROSSFEED OF ENTIRE SYSTEM

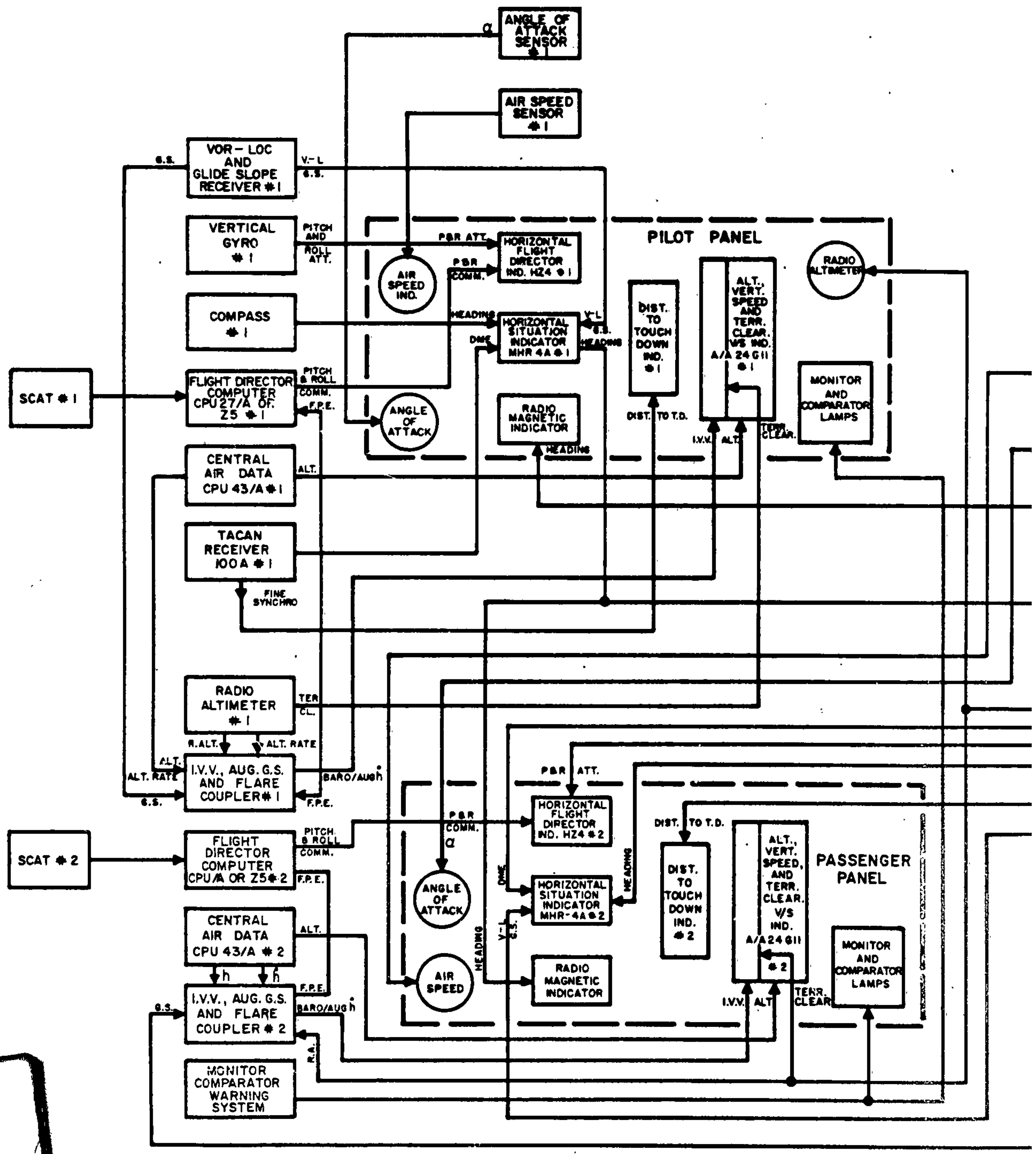
The block diagram shown in Figure 7 depicts the suggested method of interconnecting the proposed instruments, sensors, computers, etc., to provide the maximum amount of redundancy and independent crosschecks.

Briefly, the #1 Compass, #1 Vertical Gyro, #1 VOR-LOC and Glide Slope Radio, #1 Central Air Data, etc., supply the pilot's primary instruments. The other set of sensors and computers supply the presently installed co-pilot's instruments, the set of instruments to be installed in the passenger's cabin and the autopilot system.

It is shown, referring to the pilot's panel in Figure 7, that the Horizontal Situation Indicator is fed from the #1 Compass System and the Radio Magnetic Indicator is fed from the #2 Compass System, through the co-pilot's MHR4A. Redundancy was employed as far as possible. The Augmented Vertical Speed displayed on the Vertical Scale Indicator A/A24G-11 is computed using the barometric information supplied by the Central Air Data, whereas, the pitch command signals supplied to the flight director pitch command bar are computed using both air data and radio altitude information during the appropriate portion of the flight profile.

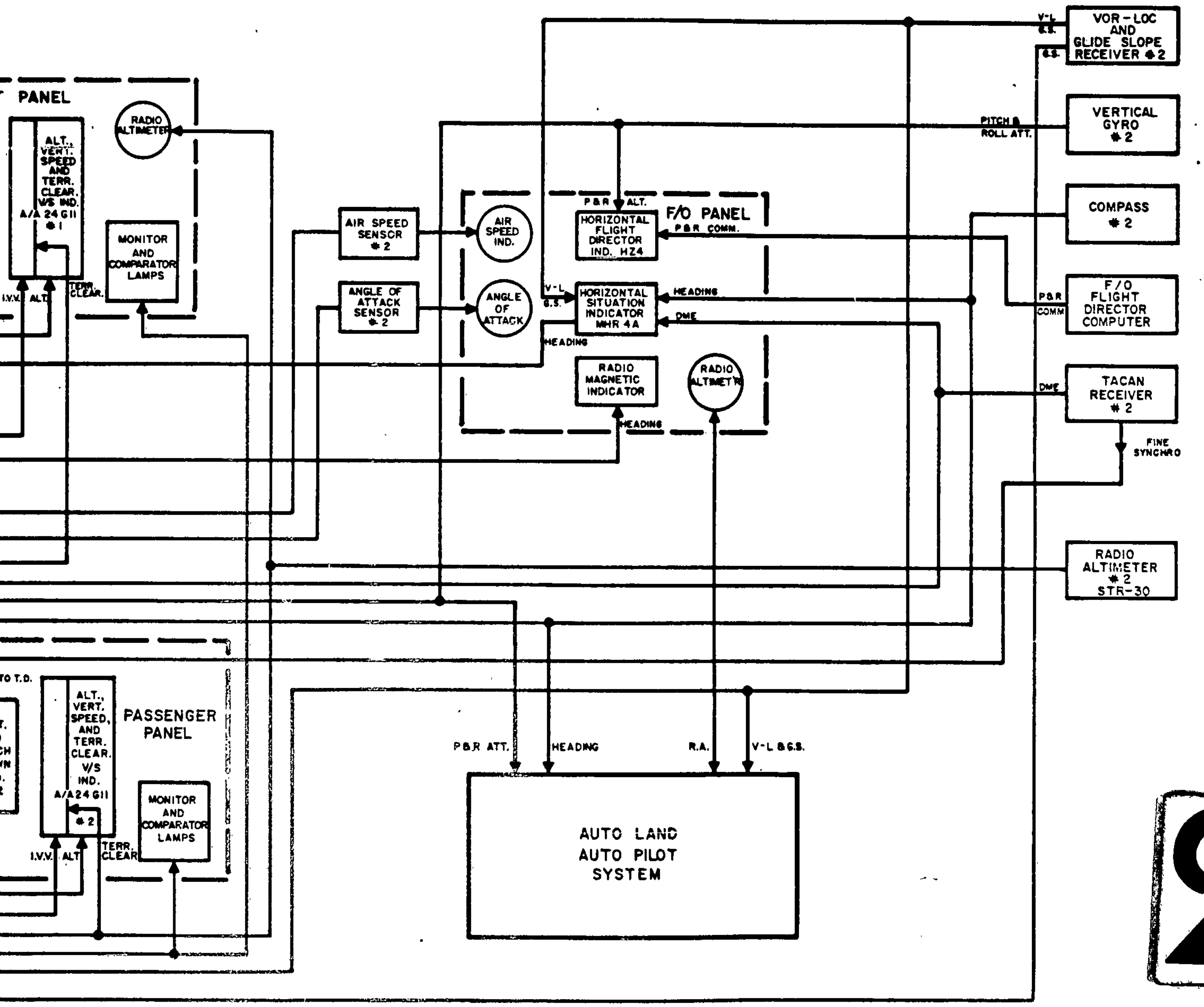
It is seen that the F.A.A. sponsored Radio Altimeter, shown as Radar Altimeter #1, Figure 7, supplies terrain clearance to the pilot's Vertical Scale A/A24G-11, whereas the pilot's Radio Altimeter is supplied by the STR 30-B presently installed unit.

It was not felt necessary to describe in detail the entire crossfeed of information shown in Figure 7. It must be emphasized that redundancy of displayed information was the prime factor governing the crossfeed proposed.



TYPICAL CROSS SWITCHING DIAGRAM USING F

FIGURE



G DIAGRAM USING FIGURE 1 AS THE EXAMPLE PANEL

FIGURE- 7

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4. SPECIFICATIONS FOR ITEMS TO BE FABRICATED

A general specification is included for items not presently available. Naturally, items which can be identified by a vendor's part number, MIL Spec or ARINC reference, are not included herein.

In the event that items specified herein are authorized for fabrication by the Project Manager, a more detailed specification will be provided.

4.1 Air Speed and Angle of Attack Vertical Scale Indicator/Amplifier

Reference: MIL-A-27670A (USAF) Spec. pertaining to the A/A24G-10 Indicator/Amplifier Group.

Method of Presentation - The method of presenting the information to the pilot, shall be by means of a moving scale to be read against a fixed-center-reference line for the aircraft indicated Air Speed, and Angle of Attack (Safe Speed).

The indicator shall present the following information derived from synchro signals from the Central Air Data Computer.

A) Indicated Air Speed (Range: 50 to 600 knots)

B) Angle of Attack (Safe Speed) (Range: -10° to + 25°) from an Angle of Attack Transmitter.

Indicator Control Transformer Synchros:

A) Indicated Air Speed	AY30/_/S-18A1	Two required to provide fine and coarse follow up. If monitoring is required, an additional synchro is needed.
B) Angle of Attack (Maximum Safe Speed)	AY30/_/S-18A1	One required.

Performance

Scale Error

Indicated Air Speed

IAS Knots	XMTR Coarse°	Angle Fine°
80	353.33	326.67
100	0	0
200	33.3	166.67
300	66.7	333.33
400	100	140.
500	133.3	306.67
600	166.7	113.33

Slew Speed

Function	Max. Time in Sec.
Indicated airspeed (50-600)	12
Safe Speed (Angle of Attack) (-10° to + 25°)	5

Accuracy

Indicated Air Speed - All readings shall not be in error in excess of 1 knot as read on the fine synchro.

Angle of Attack - All readings shall not be in error in excess of .25° angle of attack as read on the Angle of Attack Transmitter.

Operation

Indicated Air Speed - The indicated Air Speed moving scale shall be actuated by a servo mechanism with dual speed transmitting synchro input. The input to the synchro control transformer shall be linearly proportional to indicated airspeed over the range of 50 to 600 knots. Synchro electrical zero shall be at 100 knots. The tape scale factor shall be 1 1/4 inches per 50 knots with markings at every 10 knots. When the signal input is below 50 knots, the moving scale shall remain fixed at 50 knots. Electrical scale factor shall be 166.67° per 100 knots fine and 33.33° per 100 knots coarse. Servo slew speed shall be at least 2,000 knots per minute.

Angle of Attack (Safe Speed) - The angle of attack moving scale shall be actuated by a servo mechanism with synchro input. The input to the synchro control transformer shall be proportional to the angle of attack over a range -10° to + 25°. Scale factor shall be 2.7° per 5/16 inch of tape with markings at every degree. Electrical zero shall be at 0° angle of attack. Servo slew speed shall be at least 420°/minute.

Damping - A damping adjustment shall be provided, accessible externally on the amplifier for the purpose of adjusting to optimum damping characteristics.

Self Test Circuit - A self-test circuit shall be provided in the indicator so that the air speed tape may be positioned to a preset value of 225 knots.

Air Speed Monitoring Circuit - A monitoring circuit shall be provided that will detect malfunctions in the indicator components and in intercabling, included the transmitter synchro within the air data computer. A malfunction shall cause the IAS warning flag to appear. Provisions shall be included so that nuisance type warnings are not detected.

Amplifiers - The servo amplifiers shall be of the transistor-mag type amplifiers. The design shall provide for plug in modules for power supply, auxiliary circuits, and amplifier circuits.

Servo-Response

Function	Bandwidth
Airspeed	3-8 cps
Angle of Attack	2 to 5 cps

Power Requirements - The power requirements shall be of the following type:

AC Power	-	Operating Limits:	102 to 124 Volts
		Emergency Supply:	90 to 130 Volts
		Frequency Limits:	380 to 420 cps
		Max Operating V.A.:	63 VA
		Max warmup time:	2 minutes

Power Failure Indication - In the event of normal and emergency power supply failure, a spring loaded dropout flag shall be provided, red in color with black "OFF" lettering.

Lighting - The instrument shall be lighted internally in accordance with MIL-L-27160. A 400 cps voltage, variable from 0 to 5 volts rms, shall supply power for internal lighting for both normal and emergency operation.

Elapsed Time Indicator - A 10,000 hour, 4 digit type elapsed time indicator conforming to MS17322 shall be provided and so mounted in the indicator that the dial is visible on the side or rear of the case.

Weight - The weight of the indicator shall not exceed 8 pounds and the weight of the amplifier shall not exceed 7 pounds.

Size - The size of the indicator shall be 2.25 inches wide, 8 inches high and 9 inches long. The size of the amplifier shall be 4 inches wide, 4.5 inches high and 6.25 inches long.

4.2 Bendix Horizon and Director Indicator

The Bendix Horizon and Director Indicator proposed for the All-Weather Instrument Landing System, shall be a modified Bendix type 17810 Indicator. The present 17810 HDI, which is presently used by many airlines and F.A.A. certified, has a servoed attitude sphere and a servoed command display. The modified indicator shall present the following information in addition to those incorporated in the present 17810 HDI:

A. SCAT "Fast-Slow" meter movement

B. SCAT "OFF" Flag

C. Flight Director Mode Lamp Indications

D. "Dim-Bright" Lamp Control

Operation - The operation of the additional features will only be specified since the basic functions of the indicator has not changed.

SCAT "Fast-Slow" Meter Movement - The SCAT meter movement shall be actuated by means of a DC current derived by the SCAT System. The meter movement shall have the same characteristics as that used in the present SCAT Indicator. An "OFF" shutter shall appear over the SCAT meter movement when the SCAT system is either not in use or has a malfunction. The "OFF" shutter shall also be actuated by the SCAT System.

Flight Director Mode Lamp Segments - Mode lamp segments shall be situated on the left and right sides of the instrument. The mode segments shall be actuated by power supplied by the Flight Director System and shall be lettered: Alt (Altitude), G.S. (Glide Slope) on the two left segments: and SCAT, AGS (Augmented Glide Slope) on the two right segments. These segments shall have

a dull black finish with the letters engraved into them. The letters themselves shall have a light black finish so that when power is applied to an individual segment, the letters shall appear white. The brightness of the lamp segments shall be controlled by an external knob located in the lower right hand side of the indicator. The indicator shall have markings labeled "DIM" and "BRIGHT" and shall be located at the counter-clockwise and clockwise positions of the knob. The control shall also have a "press to test" feature to determine the conditions of the lamps within the indicator.

Power Requirements - The power requirements needed for the additional features shall be of the following type:

AC Power: Operating Voltage: 5 Volts

Max Operating VA: 3 VA

Weight: - The additional features shall not contribute more than .5 pounds to the present indicator.

Size: - There shall be no change in the size of the instrument.

4.3 Distance to Touchdown Indicator

Method of Presentation - The method of presenting the information to the pilot shall be by means of a moving display to be read against a fixed reference line for the aircraft distance to touchdown.

The indicator shall present distance information derived from the "Units" transmitter synchro in the DME System.

Performance

Scale Factor

Distance N. Miles	CT Synchro Angle
-1	324°
0	0°
+1	36°
2	72°
3	108°
4	144°
5	180°
6	216°
7	252°
8	288°

Slew Speed

Distance to Touchdown
(-1 to + 8 N Miles) -10 sec max.

Accuracy - $\pm$ .05 Nautical Mile for ranges from -1 to + 8 Nautical Miles.

Operation - The distance to touchdown moving display shall be actuated by a servo-mechanism with unit's transmitter synchro input from the DME system. The input to the synchro control transformer shall be linearly proportional to the distance to station over the range of -1 to + 8 Nautical Miles. The tape scale factor shall be 1 inch per Nautical Mile with graduation and numerical markings at every Nautical Mile for ranges from + 8 to + 1 Nautical Mile. A cross-hatched runway display shall represent the distance from 0 to -1 Nautical Mile. When the signal input is lower than -1 Nautical Mile, the moving tape shall remain fixed at -1 Nautical Mile.

The runway shall come in view at the top of the instrument, when a distance of 2.5 Nautical Miles is read under the fixed reference line. Electrical scale factor shall be 36° per 1 Nautical Mile. Servo slew speed shall be at least 70 Nautical Miles per minute.

Amplifier - The Servo Amplifier shall be of the transistor type and an integral part of the instrument.

Servo Response - The distance servo-mechanism shall have a bandwidth between 2 to 5 cps.

Power Requirements - The power requirements shall be of the following type:

AC Power:	Operating Limits:	102 to 124 Volts
	Frequency Limits:	380 to 420 cps
	Max operating VA:	30 VA
	Max Warmup Time:	1 minute

Power Failure Indication - In the event of normal power supply failure, a spring loaded dropout flag shall be provided, red in color with black "OFF" lettering.

Lighting - The instrument shall be lighted internally in accordance with MIL-L-27160. A 400 cps Voltage, variable from 0 to 5 Volts RMS shall supply power for the internal lighting.

Weight - The weight of the indicator shall not exceed 3 pounds.

Size - The size of the indicator shall be 1.25 inches wide, 5.875 inches high, and 5.5 inches long.

4.4 Flight Director Phase Indicator

Method of Presentation - The method of presenting Flight Director phase information to the pilot, shall be by means of lighting 3 lamp segments labeled GS (Glide Slope), Aug. GS (Augmented Glide Slope), and Flare.

Operation - The phase lamp segments shall be actuated by power supplied by the Augmented Glide Slope and Exponential Flare Module. The lamp segments shall have a dull black finish with the letters engraved into them. The letters themselves shall have a light black finish so that when power is applied to an individual segment, the letters shall appear white. The lamp segments shall also have a "press to test" feature to determine the condition of the lamps within the indicator.

Power Requirements -

DC Power:	Operating Limits:	20 to 28 Volts
	Max operating power:	2 watts per segment

Weight - The weight of the indicator shall not exceed .75 pounds.

Size - The size of the indicator shall be 1.6875 inches wide, 3.5 inches high (includes mounting flanges) and 2.0 inches long.

The size of each segment shall be 1.375 inches wide, .625 inches high, and shall extend beyond the panel by .1250 inches maximum.

4.5 Flight Director Monitor and Comparator Warning Lamps

The monitor and comparator warning lamps shall be actuated by the monitor and comparator Warning Module. The lamps shall have the "press to test" feature to determine the condition of the lamp. The additional power to actuate the lamps shall be 18 watts from the 28 Volt DC line.

4.6 Monitor Comparator Warning System

Since much can be said on the subject of monitoring, it is felt that certain philosophy schemes should be described instead of specifying detailed

monitoring and comparison circuits. A detailed specification can be written after the Project Manager has decided which schemes are to be used.

The present interlocking associated with the compass, computer and vertical gyro warning flags, (which makes use of power monitoring solely), and the countless cross checking between instrument panels, can greatly be improved and simplified by means of a monitor-comparator warning system. The following monitor and cross panel comparator schemes are proposed to indicate inherent failures of and excessive errors between prime navigational systems. These indications will be evident to both the pilot and observer by the operation of warning lamps on their respective instrument panels.

A brief description of each scheme is as follows:

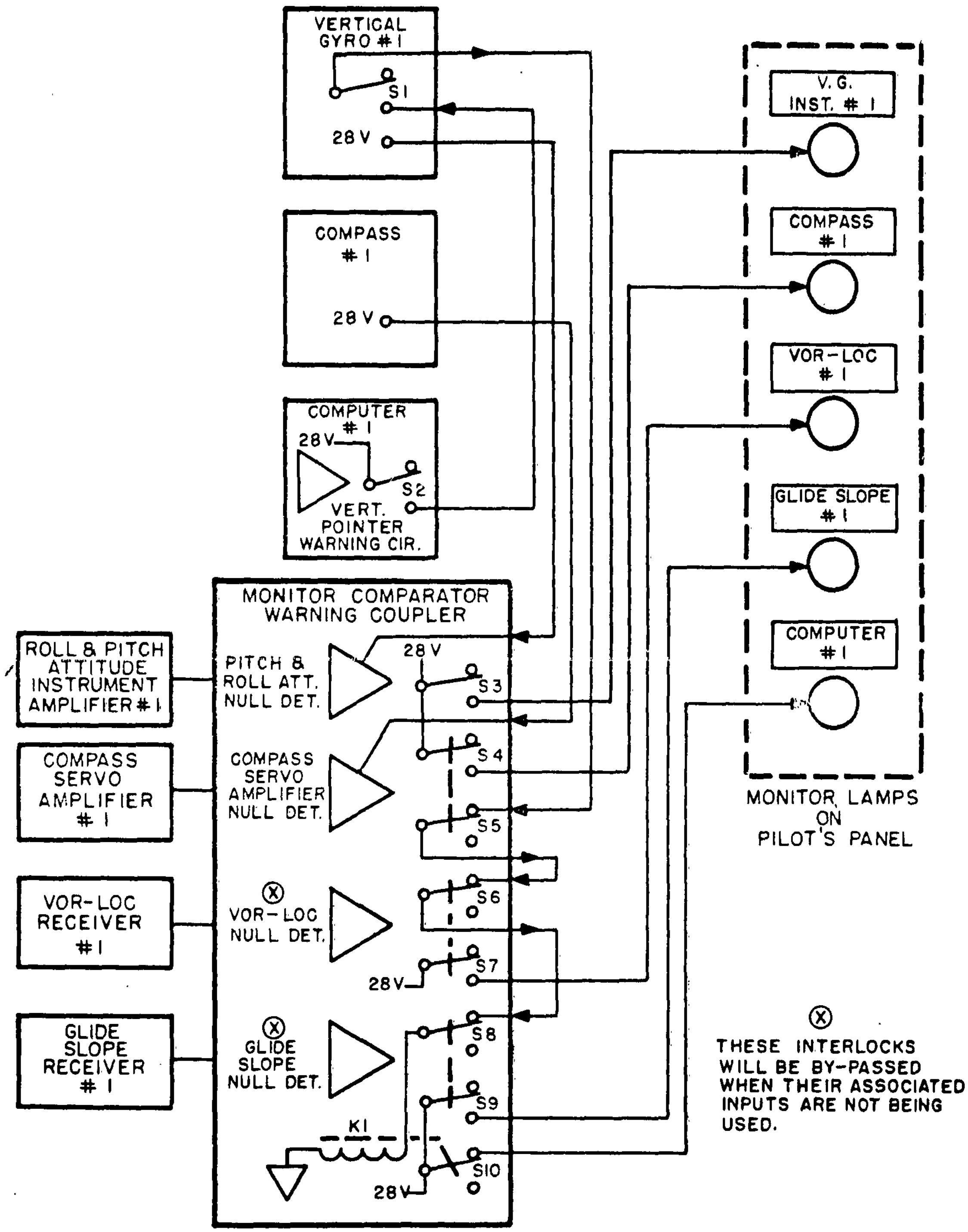
a - Pilot Panel Inherent Monitor Scheme-(Figure 8)

The #1 Vertical Gyro Instrument Warning Lamp

The Vertical Gyro Instrument Warning Scheme involves the use of 28 Volts dc supplied by #1 Vertical Gyro Erection Circuit and the use of the pitch and roll attitude null detector in the Monitor-Comparator Warning Coupler. The monitor pickoffs, are located at the inputs of the two instrument amplifiers. Hence, provisions must be made in units where the amplifiers are integrally located as in the case of the proposed Air Force Attitude Director Indicator ARU-2B/A. The null detector shall detect a multiple of failures in both the pitch and roll attitude instrument servo mechanisms. The failures to be sensed are those that occur in the motor-generator units, gear trains and instrument amplifiers. The monitor, detecting these failures and sensing the absence of the gyro erection dc voltage, closes the S_3 contacts which causes the #1 Vertical Gyro Instrument Warning Lamp to light.

The #1 Compass Warning Lamp

The Compass Warning Scheme involves the use of the 28 Volts dc supplied by the #1 Compass Amplifier and the use of the compass servo amplifier null detector in the Monitor-Comparator Warning Coupler. The monitor pickoff is located at the input of the Compass Servo Amplifier. The null detector shall detect failures in the primary compass indicator such as the Sperry Type (C6-A or MHR-4A).



PILOT PANEL INHERENT MONITORING SCHEME
FIGURE-8

The type of failures which are sensed, are those that occur in the motor-generator unit, gear train and servo amplifier. The monitor, detecting these failures and sensing the absence of the compass amplifier dc voltage, closes two pairs of contacts of which one (S4) is used to light the #1 Compass Warning Lamp. The other contact (S5) is used as an interlock in the #1 Computer Warning Scheme.

The #1 VOR-LOC Radio and the #1 Glide Slope Radio Warning Lamps

Two pairs of radio sensors shall be used to monitor the current presently supplied to the VOR-LOC and Glide Slope Warning Flags in the Horizontal Situation Indicator. The failures that are detected by the present radio warning circuits, will consequently be sensed by the VOR-LOC and Glide Slope Sensors. These sensors are actually integral parts of the VOR-LOC and Glide Slope Null Detectors in the Monitor-Comparator Coupler. Each monitor, detecting the absence of current in the individual flag circuits, energizes a double pole, double throw relay. A set of contacts (S7 and S9) of each relay, is used to respectively light the #1 VOR-LOC and the #1 Glide Slope Warning Lamps. The other sets (S6 and S8) are used as interlocks in the #1 Computer Warning scheme. It must be noted that if the mode selected by the mode selector switch does not make use of the radio inputs, these contacts will automatically remain in the de-energized positions despite the absence of current in the individual flag circuits.

The #1 Computer Warning Lamp

The computer warning scheme involves the use of 28 Volts dc supplied by the #1 Computer. This voltage shall be interlocked by:

1. Set of contacts (S2) provided by the vertical pointer flag warning circuit in the CPU-27/A Computer.
2. Set of contacts (S1) provided by the #1 Vertical Gyro Erection Circuit.
3. Set of contacts (S5) provided by the compass null detector previously described.
4. Set of contacts (S7) provided by the VOR-LOC null detector previously described.
5. Set of contacts (S9) provided by the Glide Slope null detector previously described.

If no failures are encountered along the computer warning chain the computer dc voltage energizes the K1 relay which in turn disrupts

the current to the #1 Computer Warning Lamp by means of the S10 contacts. The loss of computer power or any failures along the computer warning scheme, enables the warning relay contact (S10) to resume its normally closed position, causing the warning lamp to light. This lamp will be interlocked with the mode selector switch so that if the computer system is not in use, the #1 Computer Warning Lamp will not light.

b - Observer Panel Inherent Monitoring Scheme - (Figure 9)

The observer panel inherent monitoring scheme (monitoring of #2 set of prime navigational systems) is identical to the pilot panel inherent monitoring scheme. The second set of null detectors will be housed in the same monitor-comparator warning coupler, and will operate:

1. The #2 Vertical Gyro Instrument Warning Lamp
2. The #2 Compass Warning Lamp
3. The #2 VOR-LOC Warning Lamp
4. The #2 Glide Slope Warning Lamp
5. The #2 Computer Warning Lamp

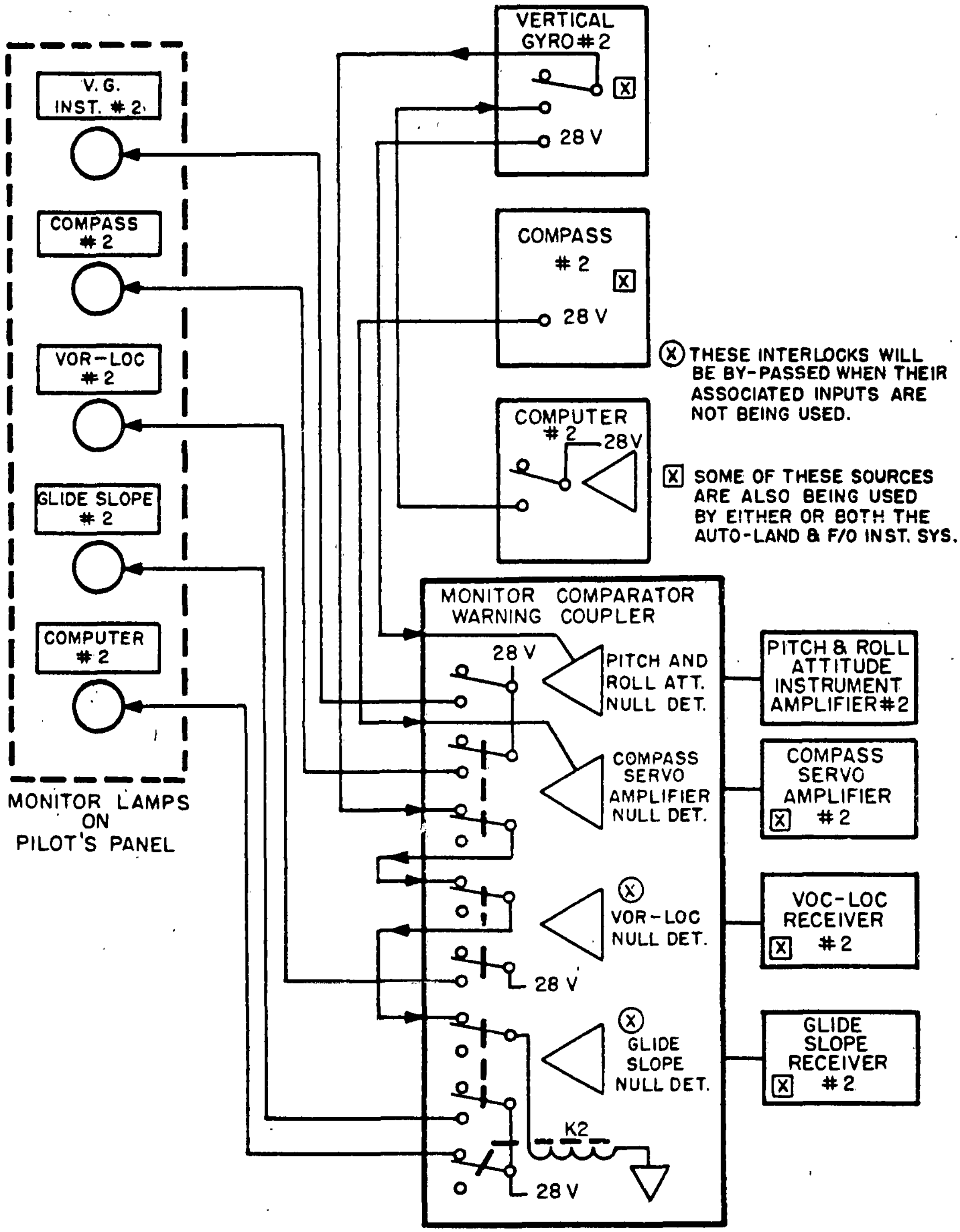
c - Pilot and Observer Cross Panel Comparator Scheme (Figures 10 and 11)

The Compass Comparator Warning Lamp

The Compass Comparator compares the difference between the #1 and #2 compass "boot strap" transmitters, which are located in the primary compass instrument (Sperry C6-A or MHR-4A). This difference is sensed by the monitor-comparator coupler which in turn activates the compass comparator warning lamp. A compensation circuit is incorporated so that a false warning is not indicated in a turn. The warning indication does not tell which system has the malfunction, but this can be deduced by the inherent monitor warning scheme.

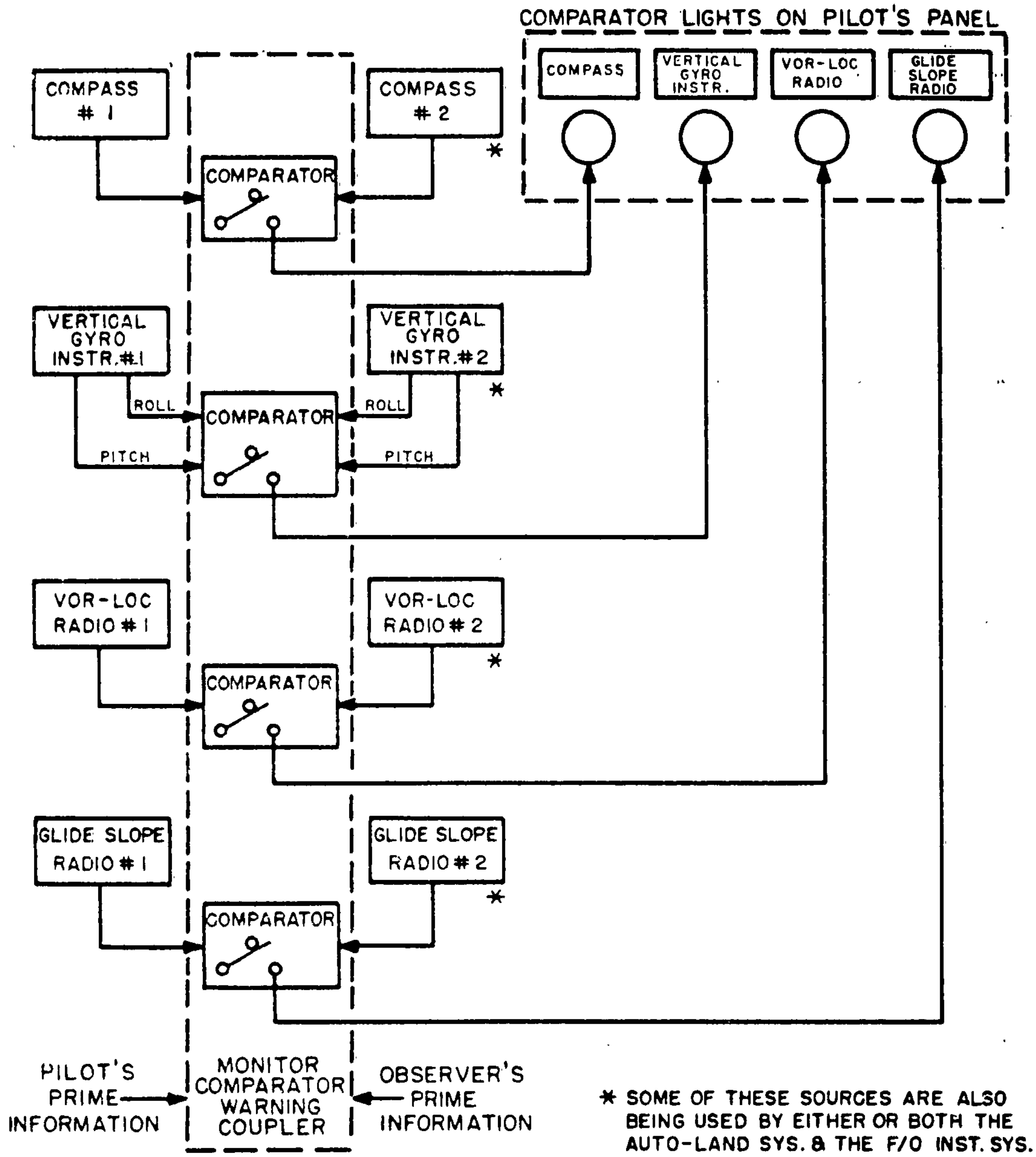
The Vertical Gyro Instrument Comparator Warning Lamp

The Vertical Gyro Instrument Comparator compares the difference of the #1 with the #2 pitch and roll "bootstrap" transmitters. These transmitters are located in the Horizon Flight Director Indicator (Sperry HZ-4). For comparison of attitude indicators which do not contain the "bootstrap" transmitters, such as the Air Force Type ARU-2B/A, another method must be incorporated to detect the difference of the prime



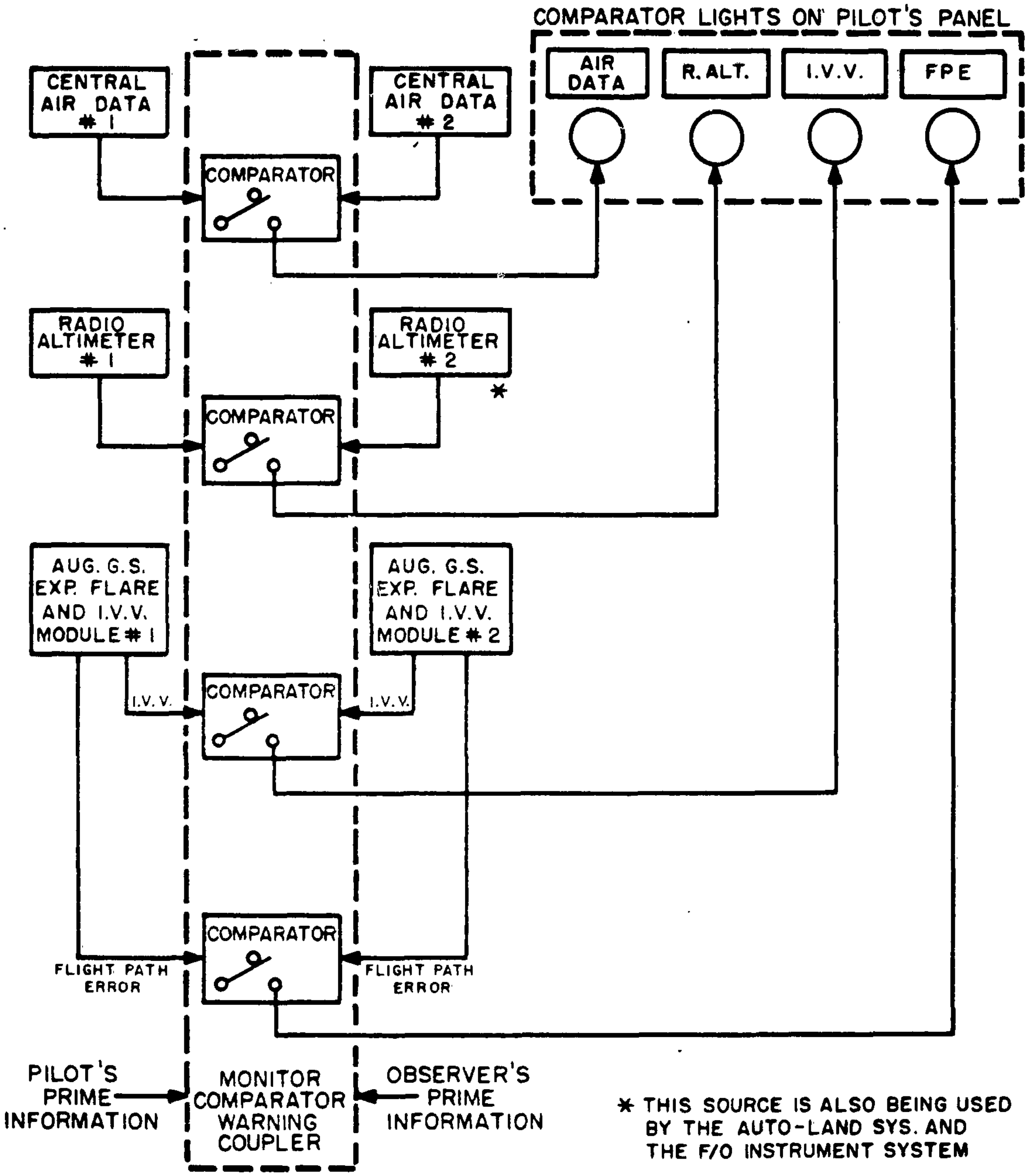
OBSERVER PANEL INHERENT MONITORING SCHEME

FIGURE - 9



PILOT AND OBSERVER CROSS PANEL COMPARATOR SCHEME # 1

FIGURE - 10



PILOT AND OBSERVER CROSS PANEL COMPARATOR SCHEME # 2

FIGURE - 11

attitude information. These differences are sensed by two comparison circuits, either of which can trigger the transistor switch which lights the Vertical Gyro Instrument Comparator Warning Lamp. For comparison of attitude indicators using electrical pitch trim, a circuit is incorporated to compensate for the trim setting. A faulty vertical gyro instrument system, can be singularly determined by the inherent monitor warning scheme.

The VOR-LOC and Glide Slope Radio Comparator Warning Lamps

The radio displacement signals are initially detected by means of sensors. Separate sensors are needed so as not to load or any way affect the radio's performance. Each sensor will be associated with a particular radio, which are the #1 VOR-LOC, #2 VOR-LOC, #1 Glide Slope and #2 Glide Slope Receivers.

The outputs of each sensor are paired off and compared by the VOR-LOC Radio and the Glide Slope Radio Comparators. These comparators will activate the VOR-LOC and the Glide Slope comparison warning lamps if appreciable errors exist in each system. Individual radios are monitored by the Inherent Monitor Warning System.

Central Air Data Comparison Warning Lamp

Since altitude is a parameter which is being used by various instrumentation systems, means is provided to check that this information is approximately correct. A simple method is used which compares the "fine" altitude signal from the #2 Central Air Data Computer. A large difference, being sensed by the Air Data Comparator, is indicated by the Air Data Comparison Warning Lamp.

Radio Altimeter Comparator Warning Lamp

The two radio altimeter informations being prime parameters in the final stages of an approach, will also be compared. Although a different radio altimeter is being considered for the instrumentation system, proper scaling of the Altimeter Comparator Circuit will give the correct indication on the Radio Altimeter Comparator Warning Lamp. Circuitry, similar to that used on the VOR-LOC and Glide Slope Radio Comparator system, will be used in this scheme.

Instantaneous Vertical Velocity Comparator Warning Lamp

To insure that the information to the altitude rate tape on the vertical scale indicator is correct, a comparator is used to check the IVV signal out of the #1 IVV module with the IVV signal out of the #2 IVV module. If an appreciable difference exists, the IVV comparator circuit will energize the IVV comparator warning lamp on the panel.

Flight Path Error Comparator Warning Lamp

The correctness of the Flight Path Error Signal on the final phases of an approach, necessitates the use of a comparator on the augmented Glide Slope and Exponential Flare Information. Upon detecting an excessive error between the #1 and #2 modules, the comparator circuit activates the Flight Path Error Comparator Warning Lamp on the panel.

The monitor and comparator circuits shall not load or any way affect the performance of the individual systems. Provisions shall be incorporated, to externally adjust the level at which the monitors and comparators shall provide a warning. A suitable time delay shall be provided into each circuit to eliminate nuisance type warnings.

Size and Weight - The coupler, which houses the monitor and comparator circuitry, shall be a 3/4 ATR short box and shall not weigh more than 11 pounds.

Power - The power requirements shall be of the following type:

A.C. Power:	Operating Limits:	102 to 124 Volts
	Frequency Limits:	380 to 420 cps
	Max. Operating VA:	70 VA
D.C. Power:	Operating Limits:	28 Volts DC $\pm$ 10%
	Max. Operating Power:	40 Watts

4.7 Distance to Touchdown Coupler

A distance coupler shall be used if the Project Manager selects to use the modified AQU-4/A Horizontal Situation Indicator. A coupler is required since the resolution of the DME potentiometer is inadequate to meet the requirements of the analog distance tape in the modified HSI.

Operation - The distance to touchdown information shall be derived from the "Unit' s" transmitter synchro in the DME System. The coupler houses a "follow-up" servo-mechanism which positions a multi-turn potentiometer. This potentiometer shall have the resolution and linearity exceeding the requirements of the HSI. The potentiometer shall have the following scale factor to make it compatible with the distance tape mechanism:

-600 Microamperes DC at 8 to 4 miles from touchdown.

-450 Microamperes DC at 3 miles from touchdown.

-300 Microamperes DC at 2 miles from touchdown.

-150 Microamperes DC at 1 mile from touchdown.

0 Microamperes DC at touchdown.

+150 Microamperes at .7 miles past touchdown.

When the signal input is lower than -.7 miles, the output shall remain fixed at -.7 miles.

Accuracy - ± .05 Nautical Mile for ranges from -.7 to + 8 Nautical Miles.

Slew Speed - The servo slew speed shall be at least 70 Nautical Miles per minute.

Servo Scale Factor:

Distance N. Miles	CT Synchro Angle
-.7	334.8°
0	0°
+ 1	36°
2	72°
3	108°
4	144°
5	180°
6	216°
7	252°
8	288°

Coupler Transducers

A) Coupler Control Transformer Synchro - Distance to Touchdown
AY 30 [/S-18A1

B) Multi-Turn Pot Resolution and Linearity to meet accuracy requirements.

C) Amplifier - The servo amplifier shall be completely transistorized.

Servo Response - The distance servo-mechanism shall have a bandwidth between 2 to 5 cps.

Power Requirements - The power requirements shall be of the following type:

AC Power:	Operating Limits:	102 to 124 Volts
	Frequency Limits:	380 to 420 cps
	Max. Operating VA:	35 VA
	Max. Warmup Time:	1 minute

Weight - The weight of the coupler shall not exceed 3 pounds.

Size - The size of the coupler shall be 1/4 ATR short.

4.8 Scat Coupler

Since the Specialties System has not completely been evaluated, the Scat Speed Control System has been proposed for the All-Weather Instrument Landing System. The SCAT System has provisions for both AC and DC output signals which can easily be made compatible to any one of the proposed instrument systems. Direct use of these output signals does not appear to warrant the use of a SCAT coupler.

4.9 Collins Peripheral Command Indicator Coupler

Collins, to this date, has not given any details on the operation of their PCI. Since these items are not known, the requirements for a coupler required to provide compatibility between the Flight Director Computer and Peripheral Command Indicator cannot be specified.

4.10 Instantaneous Vertical Velocity -Augmented Glide Slope and Flare Coupler

The coupler shall supply the following signals to provide optimum longitudinal guidance to touchdown:

1) Altitude Rate (IVV)
2) Augmented Glide Slope
3) Flight Path Error to accomplish the proper flare

Specification for Design of IVV-Augmented Glide Slope and Flare Coupler

The outputs required from this coupler are:

a - IVV for use with the Vertical Scale Vertical Speed Display
b - Flight Path Error (longitudinal) - for use with the Flight Director Computer

1. I. V. V.

General - The IVV output shall have a signal to noise ratio that does not significantly degrade the use for which it is intended, namely an instrument display.

Specific - 1) Range: 0 to 20,000 feet/minute

2) Accuracy: ± 50 feet/minute or 2% of actual velocity, whichever is greater

3) Scale Factor: 30 Millivolts, 400 cps = 60 feet/minute

4) Resolution: 25 feet/minute

5) Type of Output: 2 wire instantaneous vertical velocity signal, in phase for climb and out of phase for descent

6) Output Impedance: less than 1000 ohms

Inputs - 1) Altitude: Fine Synchro Transmitter in CADC ($360° = 5000$ feet)

2) Rate of Climb: Tachometer in CADC (250 mv = 1000 feet/minute)

3) Altitude: (Radar Altimeter - F.A.A. sponsored, or STR - 30B)

4) Rate of Climb: (Radar Altimeter - F.A.A. sponsored. The STR -30B does not provide altitude rate - Provisions must be made to generate this signal)

5) Two wire roll attitude for roll compensation

2. Flight Path Error -(Longitudinal)

This signal shall be used to provide longitudinal displacement from the glide slope and predetermined flare path during flare. The means of extending the glide slope usefullness is not specified since various methods exist. The exponential flare shall be based on Radar Altitude and Altitude Rate (IVV). Interlocks shall be incorporated so that if a failure should occur in either the Central Air Data Computer or the Radar Altimeter, the Glide Slope error shall remain to be the Flight Path Error throughout the duration of the landing.

Output - The Flight Path error shall be compatible with the Glide Slope Signal scale factor to minimize system integration problems.

Means shall be provided to indicate the mode of flight which is being displayed (GS, Augmented GS. Flare).

Inputs - The inputs to the Augmented Glide Slope and Flare Sub-Assemblies shall be IVV (independent from the IVV supplied to the Vertical Scale), Glide Slope Error, Radar Altitude and Altitude Rate.

Description - A description of the individual sub-sections were adequately covered in Monthly Progress Report #2 and so represents the design criteria for the entire coupler.

Power Requirements - The power requirements shall be of the following type:

AC Power:

Operating Limits:	102 to 124 volts
Frequency Limits:	380 to 420 cps
Max. operating VA:	100 VA
Max. Warmup Time:	2 minutes

DC Power:

Operating Limits:	28 Volts $\pm$ 10%
Max. operating power:	14 Watts

Size - The size of the IVV, Augmented GS and Flare Coupler shall be no greater than a 3/4 short ATR Case, with provisions for potentiometer adjustments and test points.

Weight - The weight of the coupler shall not exceed 16 pounds.

5. CONCLUSIONS OF STUDY PROGRAM

Each of the six proposed panel layouts provides the displays necessary to meet the requirements for the All-Weather Landing Program. The salient features associated with each configuration were previously outlined and these factors, coupled with economic considerations, modification time, etc., constitute the basis for which our recommendations are made.

It is our opinion that the choice of panel configurations can be narrowed down to three configurations, namely Configuration #1 (Figure 1), Configuration #3 (Figure 3), and Configuration #5 (Figure 5), since these constitute the major differences in panel layouts. The Vertical Scale presentation of Air Speed-Angle of Attack for the above three configurations is considered a secondary improvement in the instrument panel.

After careful consideration of all factors associated with each instrument panel outlined in this report, the recommendations shown below are listed in their order of preference.

First Preference	Configuration #1, Figure 1
Second Preference	Configuration #5, Figure 5
Third Preference	Configuration #3, Figure 3

It must be emphasized that the above choice was an extremely difficult one to make since the panel layout shown in Figure 3 provides for more growth potential in the area of a let down mode of operation, (if flight path angle is displayed on the Attitude Director Indicator).

However, the let down mode of operation was de-emphasized for use with the DC-7 All-Weather Landing Program, and the use of flight path angle for Glide Slope monitoring does not appear to be practical based on the complexity required to add ground speed correction to an air derived flight path angle as stated in Progress Report #2, Page 25.

6. PANEL INSTALLATION - PASSENGER'S CABIN

It is realized that the detail mounting provisions for the additional set of instruments to be located in the passenger's cabin has not been provided. The panel configuration will be identical to that provided for the pilot with the exception of the C6-A Gyroscope Compass Indicator(required for compass system integration), if Figure 3 is selected. Naturally, the clock is not required for this panel. As mentioned in Progress Report #2, Page 1, the replacement of a set of seats with a console assembly appears to be the most convenient method for providing the additional panel.

The co-pilot, in addition to selecting the various mode of operation and inputs to his flight director, will also supply the same information to the flight director computer provided in the passenger's cabin. In addition, the input signals for the automatic system (runway heading, radio selection, etc.), should be provided by the co-pilot from his instrument panel to allow for maximum redundancy between the pilot's display and the remainder of the system.

7. HEADS UP DISPLAY

It is our opinion that it is not possible, at this date, to specify a particular type of "Heads Up" display for use in the All-Weather Landing Program. At present, there are two promising systems undergoing flight test evaluation. Sperry Gyroscope and Eclipse-Pioneer have a heads up prototype system installed in their DC-3.

The information content displayed is basically the same with the exception of the runway symbol. Sperry computes the runway symbol whereas Eclipse-Pioneer has developed a system known as "microvision", to establish the runway location. Microvision makes use of microwave beams positioned along the runway to establish the position of the landing area. As such, a true ground referenced presentation of the runway, rather than a computer symbol, is available to the pilot.

The symbols presented, (heading, attitude, airspeed, projected flight path, etc.), are generated in basically the same manner by both companies.

In addition to flight test evaluation, Eclipse-Pioneer is conducting a simulator study to evaluate the optimum display content for a "Heads-Up" system.

It is felt that the results of a simulator study, [illegible] coupled with flight test evaluation, will provide the requirements for a heads-up display installation at a later date.

There are various problems associated with the optical system which, to date, have not been completely solved. Collimated line-of-vision gunsight displays have been known for many years. Optics for this purpose are relatively simple to produce. The target symbol covers a relatively small angle of view, and since the pilot can concentrate his vision on this one display, relatively small head motion limits are permissible. Such systems, however, appear to be inadequate for the needs of a heads up display system.

The angle of view required for a heads up display, which would be compatible with the real world, is in the order of 40° of lateral coverage and 25° of longitudinal coverage.

While a few solutions to this problem exist, the most practical appears to be what is known as the Mossaic principle. The display to be projected is multiplexed into a corresponding number of images, I_1, I_2, I_3, I_4, being conceived as the same picture element, multiplexed into four different systems. If proper

alignment is achieved, an eye placed anywhere in the field will get the same impression. Since there are no restrictions as to the number of such systems which can be stacked horizontally and vertically, there is no theoretical limit to the size of exit pupil that can be achieved. Spherical aberration is now no problem, since it can get no larger than that of a single element.

The multiplexing can be accomplished electronically or optically. It can be accomplished by fiber optics, this is an area which must be investigated.

It is thus seen that the usefulness of a heads up display depends on overcoming the wide angle coverage problems associated with the optical system and until this is done, the implementation and generation of the symbols to be displayed will provide for a very limited type heads up display.

However, the rate at which investigation and development is progressing in this area certainly indicates the feasibility of a heads up display installation in the near future.

In summary, it is not possible to suggest a specific type of hardware at this time which will satisfy the requirements of a heads up display but it must be emphasized that solutions to the various problems are foreseen in the near future.